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ANALYSIS

Are CO_2 taxes regressive? Evidence from the Danish experience

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Abstract

Denmark today carries one of the heaviest environmental tax burdens in the world, bringing in around 10% of public revenues. While evaluations have shown that the Danish CO_2 and other environmental taxes work as an effective measure to reduce emissions, a considerable barrier to increased use of these instruments today seems to be a widespread perception of their socially adverse effects. In this article, it is demonstrated that CO_2 taxes imposed on energy consumption in households, as well as in industry, do in fact tend to be regressive, and therefore have undesirable distributional effects. This holds especially for taxes imposed directly on households. To analyze this, we apply national consumer survey statistics in combination with input–output tables.

Keywords: CO_2 tax; Distributional effects; Household consumption pattern; Indirect effects

1. Introduction

In an effort to fulfil an ambitious national reduction target to reduce emissions of greenhouse gases, Denmark was one of the first countries to impose explicit CO_2 taxes on both household and business energy consumption in 1992/1993. As an effect of the 'green' reform of the Danish tax system during the 1990s, which has gradually shifted some of the burden of taxation away from incomes towards natural resources, Denmark today carries one of the heaviest environmental tax burdens in the world, bringing in around 10% of public revenues.

With one of the highest national CO_2-emissions-per-capita levels in Europe, the need to adopt ambitious national climate policies and measures was readily accepted by a broad majority in the

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Danish Parliament in the late 1980s. In an ambitious 1990 energy action programme, the Danish Government proclaimed a national target of reducing CO_2 emissions by 20% by the year 2005 in relation to 1988 levels. Later, Denmark has taken upon itself a new national target of reducing emissions by 21% of 1990 levels between 2008 and 2012, as its share of the common European Union Kyoto commitment to reduce greenhouse gas emissions by 8% of 1990 levels between 2008 and 2012. Although the effective CO_2 tax level on business energy consumption was initially very low, it was later raised considerably when an overall package of business energy efficiency measures was introduced in 1995. Since then, Danish companies have carried one of the world's highest net CO_2 tax burdens.

It has been shown that CO_2 taxation works as an effective measure to reduce Danish household and business CO_2 emissions (Andersen et al., 2000; Bjørner and Jensen, 2002; Danish Ministry of Finance, 1999). A considerable political barrier to an increased use of CO_2 taxation, however, seems to be a widespread perception of its socially adverse effects (European Environmental Agency, 1999, 2000). This perception has been substantiated by various studies that find that CO_2 taxes tend to increase tax regressivity (Pearson and Smith, 1991; Poterba, 1991a; Hamilton and Cameron, 1994; Barker and Köhler, 1998). Tax regressivity relative to income means that households with lower income pay a greater share of their resources than those with higher income.[4]

Apparently regressivity not only increases with CO_2 taxes paid directly by households, but also with CO_2 taxes imposed on industry (in this paper termed, *indirect household CO_2 taxes*) (Cornwell and Creedy, 1996, 1998; Symons et al., 1994, 1997; Hamilton and Cameron, 1994; Labandeira and Labega, 1999; Rapanos, 1995).

The aim of this study is to further examine the direct and indirect distributional consequences of Danish CO_2 taxes on industry and households, based on actual tax payments, directly and indirectly paid by households. Thus, we will evaluate the CO_2 tax burden on households in different income brackets, in order to examine whether CO_2 taxes tend to be progressive or regressive. The present study distinguishes itself by being based on empirical observations of already implemented taxes, where behavioural responses and technological change resulting from the taxes will be reflected in actual tax payments. Furthermore, the study considers urbanity in order to find out whether rural households suffer from a higher CO_2 tax burden. Previous studies of Danish households (Wier et al., 2001) found that rural households have higher energy consumption due to higher transport and heating needs.

Some other studies have also evaluated the effects of CO_2 taxes on energy consumption based on empirical data, but until now, there have been few empirical studies on their distributional effects. One of these studies (Dubin and Henson, 1988) examined the distributional effects of energy taxes using US national data from 1979 confirming that energy taxes are regressive.

The article is organised as follows: Section 2 describes the background and the content of the Danish CO_2 tax scheme. Section 3 describes the model and methodology. Section 4 presents the data applied, and Section 5 reports the results of the analysis. Section 6 summarizes the conclusions.

2. The Danish CO_2 tax

2.1. Climate policy and CO_2 tax schemes

In the late 1980s, most parties in the Danish Parliament were positive towards extending the use of environmental taxation. New environmental taxes on, e.g. waste, CFCs and packaging were all introduced in this period. It was also in the late 1980s that the report from the World Commission on Environment and Development, 'the Brundtland Report', and the International Conference on Climate Change in Toronto, brought the problem of climate change to the top of international and national agendas. Carried along by a wave of popular support, as well as Denmark's relatively high CO_2 per-capita emission

[4] In this paper, the terms "regressive" and "progressive" refers solely to tax payments out of disposable income. The tax is not necessarily progressive in the sense of referring to an increasing *tax rate* for increasing income levels. Please note, that all environmental taxes included in this study are flat rates independent of income levels.

levels (partly caused by the large share of coal used in national electricity generation), an ambitious national climate policy and energy action programme were adopted in 1990.

The first Danish CO_2 tax was imposed on top of existing energy taxes on coal, oil, gas, and electricity consumption, corresponding to an effective standard rate of EURO 13.5 (DKK 100) per ton CO_2. The tax was imposed on households from January 1992, and on businesses from January 1993. To secure international competitiveness, all businesses were reimbursed with 50% of the standard rate. Additional reimbursements were given according to the energy intensity of each company. The most energy-intensive companies were entitled to an additional reimbursement covering whatever was left of the CO_2 tax bill. A fair share of the net revenues expected from the new CO_2 tax was earmarked as subsidies for business energy conservation projects. The largest share of net revenues went to various subsidies that were largely aimed at improving the profitability of the public natural gas and power/heat projects.

Already in January 1993, a new comprehensive tax reform was launched (Danish Ministry of Finance, 1993) focusing on household energy consumption and waste production introducing taxes on water and plastic bags. Taxes on petrol were set to follow German levels, in order to avoid cross border shopping, which is considerable in a small, densely populated country like Denmark. There are almost no countries that levy a CO_2 tax on petrol. Instead, taxation of transport fuels are most often differentiated according to other environmental impacts, e.g. according to lead content, sulphur content, etc. (Ekins and Speck, 1999).

After the 1993 tax reform, the household CO_2 tax plus the household energy tax rates amounted to an effective tax level of EURO 81 (DKK 600) per ton of CO_2. The social disparities of indirect environmental taxation on lower income groups were compensated through the reduction of taxes on low incomes and an increase in child support. Ideas to rectify the socially adverse distributional effects of environmental taxation through regulatory design, e.g. the introduction of personal green allowances, have been discussed in Denmark. However, the administrative costs expected from maintaining progressive green tax systems have been seen as too high (Danish Ministry of Taxation, 2002).

Businesses were left generally untouched by the 1993 tax reform, but in 1995, the business tax scheme came to include an increased emission tax rate, supplementing the standard tax rate of EURO 13.5 (DKK 100) per ton of CO_2 with a sulphur tax of EURO 1.35 (DKK 10) per kg SO_2. Again, energy-intensive industries were entitled to a considerable reduction in the CO_2 tax, this time though, in return for entering into voluntary agreements on energy efficiency with the Danish Energy Agency, as shown in Table 1.

The total revenues from the CO_2 taxes are fed back to the business sector, largely as reductions in labour market contributions paid by employers and a smaller part through grants for investments in energy conservation and a scheme to improve working conditions in small firms.

2.2. Evaluations

Although it is widely recognised that exemptions reduce economic efficiency in CO_2 reduction, all countries other than Finland that have CO_2 tax schemes have introduced exemptions for energy-intensive industries (Ekins and Speck, 1999). The motivation for using differentiated tax rates has, in all cases, been to avoid losses of competitiveness compared to other countries. However, some studies suggest that these losses are not significant (see discussions in Baranzini et al., 2000; Barker and Johnstone, 1998; Ekins and Speck, 1998; Ekins, 1999), others suggest that uniform rates may imply considerable losses in the energy-intensive industry (Godal and Holtsmark, 2001), and finally some studies suggest that they may, in principle, involve competitive advantages in the long run (Porter, 1990).

Various studies have examined the effects and efficiency of the Danish CO_2 tax scheme (cf. Andersen et al., 2000 for a survey). In 1999, the Danish Ministry of Finance presented an evaluation of the business CO_2

Table 1
Business CO_2 tax scheme, 1995

	Light processes		Heavy processes	
	With agreement	Without agreement	With agreement	Without agreement
Tax rate (EURO/ton)	9	12	0.4	3.4
Tax rate (DKK/ton)	68	90	3	25

tax scheme (Danish Ministry of Finance, 1999). Based on an extrapolation of the data and models that had originally informed the macroeconomic estimates behind the CO_2 tax scheme, it was concluded that the scheme had created a substantial environmental effect in an economically efficient way, while taking international competitiveness into proper consideration. The CO_2 reductions originally expected had generally been realised and causes for adjustments were only minor. As for the overall national CO_2 reduction target, a deficit of 5% was identified, which was mainly the result of insufficient initiatives within the transport sector. Another study (Bjørner and Jensen, 2002) seems to point in the same general direction as the study by the Danish Ministry of Finance. Based on an extensive panel data analysis of energy prices and consumption relations, it is concluded that, in general, business energy taxes due to the CO_2 tax scheme have contributed to an overall reduction in energy consumption levels of 10% during 1993–1997.

Energy-intensive industries are entitled to a considerable reduction in the CO_2 tax in return for entering into voluntary agreements on energy efficiency, as described above. In Bjørner and Jensen (2002), it is concluded that the voluntary energy efficiency agreements have lead to a reduction in energy consumption of 9% in those industries. Another ex-post study (Pedersen et al., 1998), based on data from 1996 to 1997, estimated that the voluntary agreements had lowered emissions by 5%. This is quite interesting, as the results suggest that voluntary agreements (in return for reduced CO_2 tax payments) may in fact be as effective as taxes in reducing CO_2 emissions.

3. Methods

To evaluate the indirect effect on households of business CO_2 taxes, we use a static input–output model, which we extend with a tax matrix. Following the tradition of Duchin (1998), Lenzen (1998), Biesiot and Noorman (1999), Weber and Perrels (2000) and Wier et al. (2001), we combine input–output analysis with information on household characteristics. Thus, in the model, direct and indirect household tax payments are given for various household types, grouped according to income bracket and urbanity.

The national input–output system is used to calculate the actual indirect tax payments by households for different types of commodities based on the actual tax payments by industries. In earlier theoretical studies, these indirect tax payments were approximated by first calculating indirect CO_2 intensities of different commodities using the input–output system and then applying an indirect CO_2 tax per ton CO_2 (Symons et al., 1994; Labandeira and Labega, 1999; Cornwell and Creedy, 1996). This approach assumes that levies imposed on the industry are fully transmitted into final commodity prices. Thus, those households that demand an industry's commodities will eventually pay the CO_2 taxes first paid by industry (indirect household tax payments). We will follow this approach, recognizing, however, that the degree of transmission will depend on technological development and substitution possibilities in industries as well as in households.

Total CO_2 tax payments for household i are defined as

$$TAX_i = TAX_i^{\text{direct}} + TAX_i^{\text{indirect}}, \tag{1}$$

where TAX_i is total CO_2 tax payments from household i, $\mathrm{TAX}_i^{\text{direct}}$ is direct CO_2 tax payments from household i, and $\mathrm{TAX}_i^{\text{indirect}}$ is indirect CO_2 tax payments from household i.

The analysis is carried out in two steps:

- First, direct CO_2 tax payments from households are analysed using a simple matrix model.
- Second, indirect CO_2 tax payments are analysed using an input–output model that also incorporates a CO_2 tax matrix.

3.1. Direct CO_2 tax payments

Eq. (2) describes CO_2 tax payments from direct energy requirements of household i as the product of the total direct energy consumption and the CO_2 levies per unit of energy consumed:

$$TAX_i^{\text{direct}} = \boldsymbol{Q}_i \boldsymbol{T}, \tag{2}$$

where $\mathrm{TAX}_i^{\text{direct}}$ denotes a scalar of total direct CO_2 tax payments from household i in units of EURO (or DKK), $\boldsymbol{Q}_i$ is a 1×3 vector including the consumption of three types of energy in household i (electricity, heating oil and natural gas), in units of GJ, $\boldsymbol{T}$ is a 3×1 vector of CO_2 tax payments per unit of GJ for three energy types (electricity, heating oil and natural gas).

Note that there is no CO_2 tax on petrol, because, as explained above, in 1993 it was decided to generally follow German petrol price levels.

3.2. Indirect CO_2 tax payments

In Eq. (3), the CO_2 tax payments from indirect household energy requirements are calculated by the following model:

$$TAX_i^{\text{indirect}} = \boldsymbol{T}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{C}\boldsymbol{c}_i \qquad (3)$$

where $\text{TAX}_i^{\text{indirect}}$ denotes a scalar of total indirect CO_2 tax payments by households as a consequence of the consumption of goods and services, in units of EURO (or DKK), $\boldsymbol{T}$ is a 1×130 vector of total CO_2 tax payment per unit of production in 130 industry sectors, $(\mathbf{I}-\mathbf{A})^{-1}$ is the 130×130 Leontief inverse matrix, with $\mathbf{A}$ being a 130×130 coefficient matrix describing intersectoral commodity flows, $\mathbf{C}$ is a 130×72 matrix of the composition of consumption commodity aggregates, i.e. 72 private consumption commodity aggregates apportioned by production sectors, $\boldsymbol{c}_i$ is a 72×1 vector including consumption of 72 commodity aggregates in household i, in thousands of EURO (or DKK).

To estimate the indirect tax payments, we apply the input–output technique to consider the total (infinite) chain of intermediate deliveries from industry to industry (using the Leontief inverse matrix, cf. above), needed to produce household consumption goods. However, the estimates of the indirect CO_2 tax payments suffer from some uncertainty, as the model neither distinguishes between different commodities produced by the same branch, nor does it distinguish between different commodities grouped in the same commodity aggregate. The model furthermore assumes tax payments to be linear in production for each industry sector. However, since the CO_2 tax rate varies across process types, this premise holds only if the energy consumption mix (i.e. distribution on space heating, light and heavy processes) does not change across production levels within each sector. Additionally, as previously stated, levies paid by the industry are assumed to be fully transmitted into prices. Please note that the assumption of levies being transmitted is associated with uncertainty. The tax on CO_2 emissions will make it optimal to reduce energy consumption in production, but producers may be gradually adjusting to this optimum. As business taxes have been imposed since 1993, some of this adjustment had already been carried out by 1996, when data for the present study was collected. However, indirect household tax payments may in fact be lower in the long run, if producers can reduce energy consumption further. Thus, the indirect CO_2 tax payments should be interpreted as a rather rough estimate.

4. Data

All data used in this study are compatible, as they apply identical classifications of goods and activities, making it possible to utilize the data in an integrated model. The data used for the present analysis are:

- Danish *input–output tables* for the year 1996 from Statistics Denmark, (tables documented in Statistics Denmark, 1986). These tables comprise 130 production sectors and nine categories of final demand. One of the latter is private consumption, which is divided into 72 components, 5 of which are direct energy consumption by households.
- *Tax vector* for the year 1996 (special service from Statistics Denmark) containing CO_2 tax payments from 130 production sectors.
- The *consumer survey* from Statistics Denmark (Statistics Denmark, 1999). The survey comprises the consumption of 1334 commodities by 3438 representatively selected households. The survey data applied in the present study are based on data from 1996. Various characteristics of the households are registered, e.g. number and age of children and adults, type of accommodation, urbanity, socio-economic status, education and type and level of disposable household income and expenditure. Three hundred ninety family types can be distinguished. Data are collected through registration of household purchases on a daily basis, supplemented by personal interviews and information from the registers. The respondent rate is 68.5%. As a final step in the calculation

procedure, the data are adjusted for the proportion of non-respondents, in order to give each household type the appropriate weight.

5. Results

5.1. The direct and indirect household CO_2 tax payments

In 1996, the direct household tax payment was 253 million EURO (DKK 1.88 billion). The indirect household payment (taxes paid by industry, but fully transmitted in final consumer prices) was 75 million EURO (DKK 0.56 billion)—approximately one third of direct household payments.

Looking at tax payments across commodities, large variations are revealed. Direct household tax payments are associated with energy commodities, and these payments are much higher than indirect tax payment per EURO 100 consumed, simply because of the high CO_2 content in these commodities. Electricity is the most heavily taxed energy type (83 EURO per 1000 EURO consumed), second is oil (60 EURO per 1000 EURO consumed) and third is gas (43 EURO per 1000 EURO consumed).

Turning to indirect household CO_2 tax payments, Table 2 lists the five commodities with the highest and the five commodities with lowest tax payments in 1996 as a percentage of total household consumption of the commodity. As can be seen in Table 2, the commodities with the highest indirect CO_2 tax liabilities are water, travel, and various types of food. In contrast, the five commodities with the smallest CO_2 tax rates are mainly services and financial transfers.

Table 2
Indirect CO_2 tax payments per commodity: top 5 and bottom 5, 1996

Number on list	Commodity	Tax payment (%)	CO_2 intensity (kg CO_2/EURO 100)
Top 5			
1	Water supply and sewerage services	0.39	44.3
2	Package holidays	0.38	61.7
3	Dairy products	0.26	46.1
4	Refuse collection and treatment	0.22	27.6
5	Butter and oils	0.22	42.8
Bottom 5			
5	Insurance services	0.07	7.7
4	Purchase of vehicles	0.04	5.6
3	Cigarettes and tobacco	0.04	5.1
2	Domestic services	0.04	5.8
1	Gross rent	0.03	4.5

Comparing tax payments with CO_2 intensities across commodity groups reveals that there is no proportional relationship between tax payments and CO_2 content for each commodity group. The highest CO_2 emissions per EURO 100 consumed are observed for package holidays and dairy products, but these commodity groups do not carry the highest tax payments as a percentage of consumption. These discrepancies are due to reductions in the tax rates on energy-intensive industries following voluntary agreements on energy conservation within the industry.

The large variation in CO_2 tax payments indicates that different household types, having different lifestyles and consumption patterns, are likely to differ significantly with regard to CO_2 tax payments. This is examined in the following.

5.2. Distributional effects of the CO_2 tax

5.2.1. Annual income results

The distributional impact of environmental taxes can be examined by looking at tax payments relative to annual disposable income for the deciles. As income rises, a falling share going to environmental taxes indicates a regressive tax. Fig. 1 shows CO_2 tax payments broken down on income deciles.

Fig. 1 suggests regressivity in tax payments (please note that the regressivity is explicitly measured in Section 5.4 below); direct as well as indirect tax payments increase with income, but constitute a smaller and smaller share of disposable household income.

In 1996, the average household paid around EURO 81 (DKK 599) in direct and EURO 30 (DKK 225) in indirect CO_2 taxes per year. Low-income households (1st decile, i.e. bottom 10% of income units) paid 25% less direct and indirect CO_2 taxes in 1996, compared to the average Danish family. High-income households (10th decile, i.e. top 10% of income units) paid 40% more direct and indirect CO_2 taxes in 1996, compared to the average Danish family. In spite of

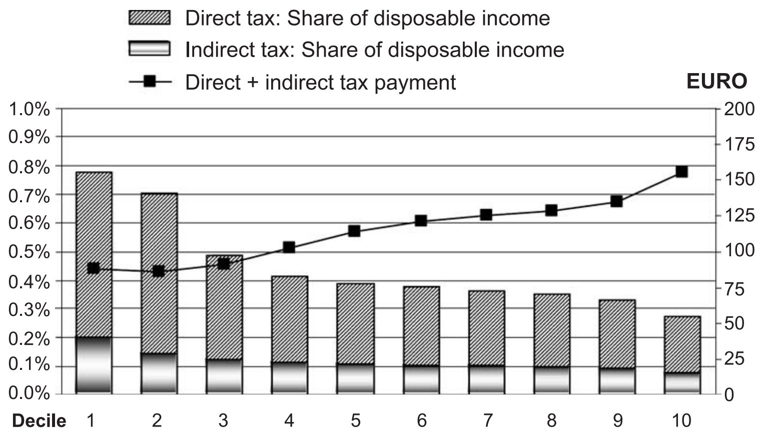

Fig. 1. Direct and indirect household tax payments (EURO) by income deciles, 1996.

these differences, however, low-income families paid (direct as well as indirect) CO_2 taxes constituting around 0.8% of disposable household income, while high-income families paid CO_2 taxes constituting around 0.3% of disposable household income.

5.3. Expenditure results

Rather than using annual income results, it may be preferable to consider regressivity in relation to total household expenditure. This is relevant for two reasons: First, the tax base is expenditure, making it relevant to measure regressivity relative to expenditure. Second, since households seek to smooth consumption over the life cycle, and therefore consume according to permanent income, actual (annual) income may be inappropriate for measuring regressivity. For example, most often, households earn their highest income around middle age. For low-income households, the choice of income measure is particularly important because many households with a current low income are students or pensioners with higher lifetime incomes. Thus, the choice of income variable for constructing deciles is not as straightforward as the results in Poterba (1991a,b), Walls and Hanson (1999) and Metcalf (1999) indicate. They find that choosing lifetime income measures (often approximated by current expenditure) rather than the current income produces less regressive tax results. Lyon and Schwab (1995), however, find very little difference in their annual income ad lifetime income results. Following Poterba (1991a,b) and Metcalf (1993), we also use total expenditure and compare the results. However, this part of the analysis is associated with considerable uncertainty, as total annual expenditure is predicted from household expenditure during a 2-week period. Even though all types of households are represented during all weeks in a year, this estimate is highly uncertain. Fig. 2 shows direct and indirect CO_2 tax payments as percentage shares of disposable income and of total expenditure. As can be seen from the figure, the regressivity of CO_2 taxes decreases when using total expenditure (please note that the regressivity is explicitly measured in Section 5.4 below). This result provides evidence in favour of the findings of Poterba (1991a,b), Walls and Hanson (1999) and Metcalf (1999). The less regressive effect of a CO_2 tax, when looking at lifetime income, suggests that any compensation scheme should focus on those persons/groups that will not be able to equalize low income in part of their life with higher incomes in other parts, e.g. single parents with low level of education, and retired persons with public old age pensions as their only potential income source.

5.4. Measuring regressivity

To assess the regressivity of a tax system, it is useful to apply the Gini index, which is defined by the proportion of the area under the diagonal that lies between the diagonal and the Lorenz curve. The

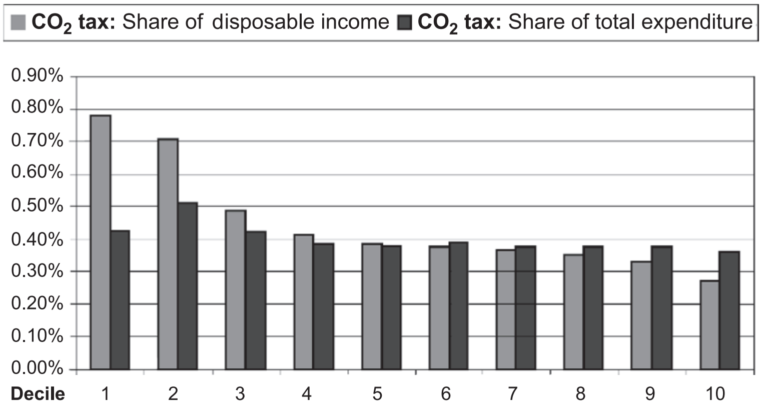

Fig. 2. CO_2 tax payments as percentage shares of disposable household income and total expenditure, 1996.

Lorenz curve in this study relates the cumulative percentage of aggregate disposable income less tax payments to the cumulative percentage of the population, cf. Dorfman (1979). Introduction of a regressive tax will make the Lorenz curve more convex, and hence the area under the diagonal larger. In the present study, we consider the marginal Gini indices, which is defined as the change in the Gini index after collecting an additional DKK 100 million in taxes (following the method applied by Jørgensen and Pedersen, 2000). Positive changes indicate regressive tax burden, and vice versa.

The Gini index is estimated relative to disposable household income as well as relative to total household expenditure, cf. Section 5.3 above. Furthermore, to support the analysis, we apply an alternative measure of regressivity, namely the Suits index (Suits, 1977). The Suits index provides additional information as it concentrates on the aggregate income of the richer rather than their number (Kakwani, 1987). The Suits index varies from −1 to 1, but this time negative values indicate regressivity and positive values indicate progressivity.

Table 3 shows the marginal Gini and Suits indices for direct CO_2, indirect CO_2, and total CO_2 taxes in 1996. In addition, the Gini and Suits index for the value added tax (VAT) and for all other Danish levies on commodities are shown. As appears from the figure, the CO_2 taxes are more regressive than the average Danish levy, and direct CO_2 taxes are more regressive than the indirect CO_2 taxes. Furthermore, the VAT is less regressive than the CO_2 tax, and petrol taxes are in fact progressive. These results hold when using the Gini as well as the Suits index.

Turning to the last column, the Gini index estimates support the picture from Section 5.3—the regressivity of CO_2 taxes decreases when using total expenditure. The direct CO_2 tax, as well as the total

Table 3
Measures of regressivity in tax payments, 1996

Type of levy	Marginal Gini index based on disposable income (%)	Suits index based on disposable income	Marginal Gini index based on expenditure (%)
Direct CO_2	0.021	−0.168	0.007
Indirect CO_2	0.015	−0.125	−0.011
Direct and indirect CO_2	0.019	−0.156	0.002
Petrol	−0.007	0.065	−0.092
VAT	0.016	−0.133	−0.009
All types of levies	0.013	−0.111	−0.019

Positive values of marginal Gini Coefficients indicate increasing regressivity, and negative values indicate increasing progressivity. Positive values of Suits coefficients indicate progressive tax burden and negative values of Suits coefficients indicate regressive tax burden.

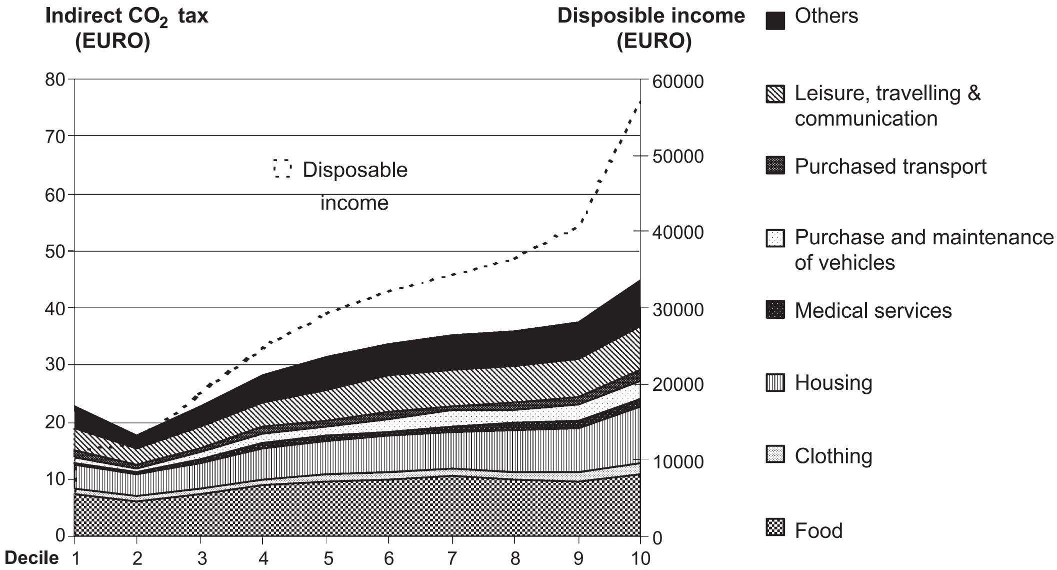

Fig. 3. Disposable income and indirect CO_2 tax payments by commodity types and income deciles, 1996.

direct and indirect CO_2 tax, is still regressive, but the indirect CO_2 tax is now progressive—and so are the VAT tax and average Danish levy (the all types of levies-category).

5.5. The importance of consumption pattern

Consumption patterns tend to change with increasing income. The budget share of necessities such as food and heating decreases and the budget share of luxuries such as travel, entertainment and other recreation activities increases with income. As demonstrated in Section 5.1, indirect CO_2 tax payments vary considerably across commodity types. Fig. 3 shows indirect CO_2 tax payments broken down by commodity type and income decile. The dotted line shows average disposable household income for each of the 10 income deciles.

As can be seen, tax payments are increasing with income, but relatively more, however, for luxury goods such as leisure activities, travel, communication and vehicles. The major share of indirect tax payments comes from the consumption of food and housing in all income deciles. The housing category includes regular rent and mortgage payments, furniture, energy and water equipment and services, plus domestic help and services. With increasing income, the indirect CO_2 tax load changes from the consumption item “rent payments” to “mortgage repayments”, and the indirect tax payments for “repairs”, “refuse removal” and “furniture” increases.

5.6. The importance of household size

Direct and indirect household energy consumption increases with household size, so larger families will have a higher CO_2 tax payment burden than smaller families. However, larger households may have lower CO_2 tax payments per head (according to scale effects in consumption) than smaller households. Consequently, family size is influencing CO_2 tax payments. Fig. 4 shows CO_2 tax payments per household, per head (capita) and per adult equivalence unit[5] in the household for each income decile. As can be seen, the differences across income deciles are smaller when looking at per capita or per adult equivalence unit payments than per household payments. From Fig. 4, it can be concluded that controlling for differences in household size (by looking at per equivalence unit payments rather than per household payments) across

[5] The adult equivalence scale (number of adults)$^{0.8}$+1/2 (number of children)$^{0.8}$ is used (following the Danish Ministry of Finance) to account for scale effects in consumption.

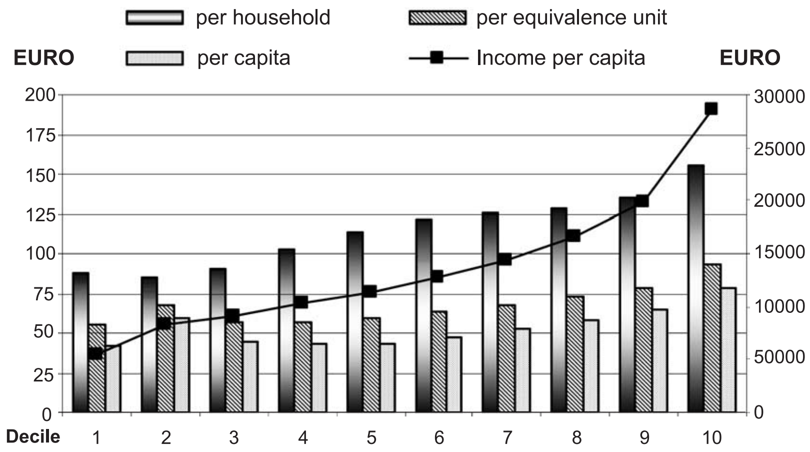

Fig. 4. Total CO_2 tax payments per household, per adult equivalence unit, and per capita, 1996.

income deciles increases regressivity, as high-income families are, in general, bigger than lower income families. Thus, higher income households are generally consuming more (and therefore pay more taxes), but part of that extra consumption stems from the fact that higher income households also have on average more family members. The alignment of per capita figures over income deciles in Fig. 4 supports the regressive picture of CO_2 taxes, as household income per capita grows substantially when going from decile 1 to decile 10 on the income scale.

5.7. The importance of urbanity

There are considerable differences in direct energy consumption between rural and urban house-

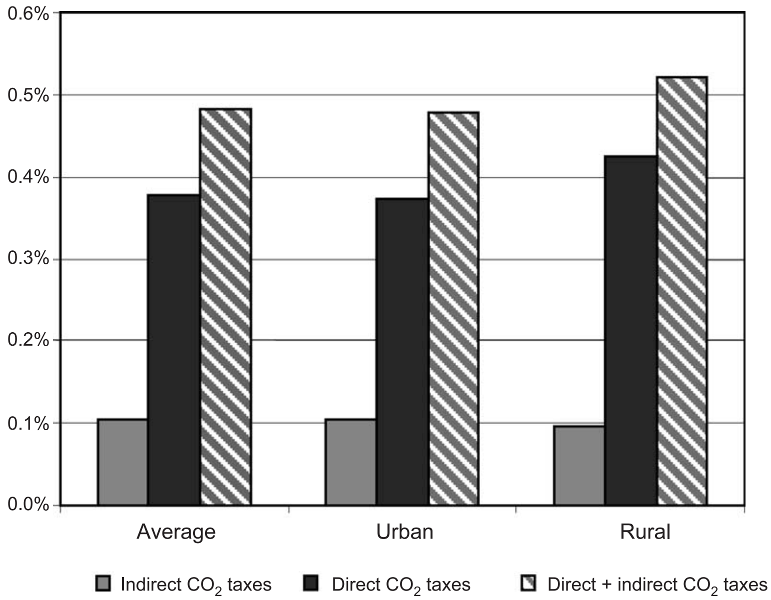

Fig. 5. Urban and rural CO_2 tax payments as a share of disposable income, 1996.

holds in Denmark, as transportation and heating needs are much higher for families living in rural areas. Indirect energy consumption does not vary significantly with urbanity (Wier et al., 2001). Fig. 5 shows direct and indirect CO_2 tax payments relative to disposable income for families in rural and urban areas. As household size does not vary considerably with urbanity, the influence of this variable is disregarded in the following. As can be seen from the figure, direct CO_2 tax payments constitute a higher share of disposable income for families living in rural areas due to their higher direct energy requirements. For indirect CO_2 tax payments, the opposite holds: CO_2 tax payments constitute a slightly lower share of disposable income for families living in rural areas. Hence, there is only a small difference in total CO_2 tax payments between families living in rural and urban areas of 0.04 percentage points.

The differences in direct as well as in indirect CO_2 tax payments are due to underlying differences in consumption patterns. Tax payments from consumption of food, clothing, and housing are similar for families living in urban and rural areas. In contrast, significant differences are observed for the purchase of vehicles, which is higher for rural families, and consumption of purchased transport, leisure activities and travel, which is higher for urban families. Correspondingly, looking at direct CO_2 tax payments, rural families have higher tax payments, primarily due to higher consumption of heating and electricity.

6. Conclusions and policy implications

Our study demonstrates that Danish CO_2 taxes are regressive, and this result holds for direct as well as indirect CO_2 tax payments. While both types of CO_2 tax payments are increasing with disposable household income, they constitute a still smaller share of the budget as income increases. The CO_2 taxes are more regressive than the average Danish levy, including VAT taxes, and direct CO_2 taxes are more regressive than the indirect CO_2 taxes. The same regressive result holds, to a lesser extent however, when applying total household expenditure instead of disposable income.

Our results also suggest that inequality exists between households that differ with respect to urbanity, and this is particularly so for direct CO_2 tax payments. Household consumption patterns, and thus CO_2 tax payments, vary considerably with both household income and urbanity, making high income households pay more taxes due to their higher consumption of leisure activities and communication, private transport, and travel. On the other hand, low-income households suffer from high tax payments due to their relatively high consumption of food and public transport and rural households suffer from high tax payments due to their relatively high demand for heating, electricity and transport.

Taxing CO_2 emissions is an often debated and recommended policy instrument to combat climate change. In several countries, “green” tax reforms have been introduced, and in many countries, similar reforms are proposed, as a mean to reduce the environmental load of modern society (Schlegelmilch, 1999; European Environmental Agency, 2000). Nevertheless, as demonstrated in this article, CO_2 taxes imposed on energy consumption in households and industry tend to be regressive, thus often having undesirable distributional effects. This result also holds for most other green taxes imposed on Danish households, cf. Jacobsen et al. (2003). An important exception, however, is the petrol tax. CO_2 emissions may be reduced by including petrol in the CO_2 tax scheme or alternatively by imposing petrol taxes rather than CO_2 taxes. Petrol taxes may not be as effective in reducing CO_2 emissions as a CO_2 tax, but they do ensure progressivity, cf. Table 3.

As most green taxes appear to be regressive, governments might have to ensure that sufficient compensation measures are in place to reduce the burdens on low-income households. In order to secure the social acceptability of environmental tax regimes, it seems somewhat essential to supplement green taxes with compensatory measures that outweigh the distributional effects if such policies are to be widely introduced in other countries in the coming years. Such measures might be introduced directly as part of the green tax regime, e.g. by the introduction of special green allowances, or indirectly through the reduction of other types of taxation.

In Denmark, the administrative costs expected from maintaining progressivity directly in the green tax systems themselves have been seen as to high. Policymakers have instead chosen to compensate the socially adverse effects of green taxation through reductions in other types of taxation. While this solution might have been more cost-effective, it will also have its limitations. First, its effective application is probably, to some extent, dependent on existing tax structures, making it somewhat easier to apply in countries like Denmark, where general tax levels are high and there is a broad array of applied tax bases to chose from, when taking compensatory measures. In countries with lower tax levels and less applied tax bases to choose from, it might be more expedient to build social compensation measures directly into the structure of the new environmental tax regimes. Second, the solution can prove weak over time, as people will have a tendency to forget how they were compensated years back from the socially adverse effects of a current environmental tax regime. The perception of environmental taxation as socially adverse might in this way rise over time if the compensatory measures cannot be pointed out clearly as an integral part of the environmental tax regime itself.

Some countries have tried to build progressivity directly into the green tax systems. A progressive scale for charging households for water consumption and wastewater treatment is, e.g. currently being used in Portugal. Likewise, in The Netherlands, tax-free lower income brackets have been introduced successfully (European Environmental Agency, 1999). Other, more focused measures could be to subsidize household energy conservation activities or to subsidize exposed households, such as single parents with low education, or retired persons with public old age pension as their only income source.

Since direct CO_2 taxes are more regressive than indirect CO_2 taxes, another way to reduce regressivity is to shift the tax burden from taxes imposed on households to taxes imposed on business. Such changes in the CO_2 tax scheme might be implemented in conjunction with measures to secure international competitiveness. Some studies, however, suggest that the competitiveness losses are small. Furthermore, if the CO_2 tax scheme applies voluntary agreements for energy intensive industries, part of the possible losses of competitiveness are avoided. Empirical results suggest that voluntary agreements (in return for reduced CO_2 tax payments) may in fact be as effective as taxes in reducing CO_2 emissions.

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