Distributional effects of an increase in the Carbon Tax within a partial equilibrium framework- the case of Sweden

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I Introduction and aim of the paper

Fiscal measures aimed at reducing the demand for environmentally sensitive goods and services (ESGS), has come to be seen as a necessary tool for moving in a more sustainable direction. Changes in prices, brought about by taxes and subsidies, will almost always have distributional effects.

The distributional effects of fiscal measures in the environmental area have had to take a back seat, for many years, in relation to the pros and cons in terms of the environmental effects. This is perhaps not surprising, as the chief interest from economists, with regards to market based instruments for the environment, have been in the efficiency properties of these instruments.

However, in recent years, the distributional effects have received increasing attention in many countries. In most countries, ESGS such as petrol consumption, claim a higher share of total expenditures for low income households than it does in higher income households. This implies that a fiscal reform aiming at increasing, for instance, the price of petrol, will affect the total expenditures of low income households more than the total expenditures of high income households.

This is more or less evident from just looking at the expenditure patterns in different countries. The changes in prices brought about by the tax changes will of course alter the composition of the expenditures. Households will adapt its expenditure to reflect that some goods and services have become relatively more expensive. Depending on the price effects between substitutes, some reallocation of expenditures would be expected. This adds another dimension to the effect of the increase in the prices of ESGS in different types of households.

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A fiscal reform on ESGS is mainly argued along efficiency lines, i.e. that the price changes introduced are corrective in the sense that these goods and services can be seen as having been subsidised so far. Prices have not included the true cost of consuming them. The tax, or levy, can be seen as an attempt to correct this implicit subsidy.

There is also another side to this kind of tax or levy. As other taxes, it generates revenues. In many cases, taxes are introduced for no other reason than to generate revenue, but a corrective environmental tax does not primarily have this purpose.

Revenues can, however, be used in different ways. They could, for instance, be targeted to increase the efforts in the environmental field in general. It is also possible, and probably necessary, to consider using the revenues to reduce other taxes. On the one hand this could be seen as a way of keeping the total tax pressure constant. On the other, this has been introduced in the debate as a possibility to substitute taxes that have greater distortionary effects. This is part of what the debate on the, so called, double dividend has focused on. Another possible use of the revenue is of course to alleviate the expected distributional effects of the fiscal measures on ESGS. Most economists would prefer some kind of lump sum transfer to counter act the distributional effects, but this is perhaps not possible in most countries.

In this paper the focus is on the distributional effects of a change in the carbon tax for Sweden. The analysis is done from a demand side point of view, i.e. in a partial equilibrium framework. The tax and revenue side of the change is also modelled in order to be able to look at possible compensations and the changes in tax revenues.

The results are not really surprising. A doubling of the carbon tax will have negative distributional effects regardless if one look at expenditure group, disposable income groups, or regional groups.

A compensation through a decrease in the VAT has been suggested as a remedy for these negative effects. A revenue neutral decrease in the VAT will change the levels of, but not erase, the losses. All household categories have to be compensated in order to achieve the same welfare as before the change. The less well off households will suffer more than the more well off households.

The net loss due to the tax change should naturally be viewed against and compared to the presumed gain from a better environment. This is really the purpose of the tax change in the first place.

The calculations in this paper is based on a Linear Almost Ideal Demand system model. It has been estimated for durable goods as one category and then 12 aggregated non durable goods, where it is assume that the household first allocates its income between durable and non durable goods and then within the non durable goods.

The estimations are based on both macro data and micro data. The price elasticities are based on the data from the national accounts on final private consumption, while the income/budget elasticities are based on data from a household budget survey. This combination of time series and cross section is really a second best solution compared to having a series of expenditure surveys.

A household budget survey is the only source for doing distributional analysis of consumption and expenditures. Most countries make household budget surveys, with varying intervals. The trend in the member states seem to be towards having annual expenditure surveys with reduced samples, compared to the intermittent surveys. This is promising for future analysis. The classifications used, in terms of household types, in the comparative tables published by Eurostat have apparently shifted from incomes to expenditures. And to further complicate matters the expenditure classification is not in deciles or quintiles, but in expenditure groups in relation to the mean expenditure. This shift from income to expenditure is probably mostly due to the poor income estimates in many countries.

Looking at the possibilities of using the national accounts data and household budget survey data as it is compiled at Eurostat poses some interesting problems when using these kinds of data for distributional analysis.

One is due to the problem of specifying what constitutes an economically weaker household. Traditionally, the use of income as an indicator of the level of resources at a households disposal has been rather straight forward. The relevant base for the evaluation in terms of adult equivalents have, on the other hand, been the subject of much debate. How does the change in focus to expenditure groups alter the possibilities of finding vulnerable groups? Does a lower level of expenditures really mean that the household is economically weaker than an otherwise comparable household with a higher level of expenditure?

The other problem has to do with the discrepancies between private consumption as it is calculated in the national accounts and private consumption as it comes out in the household budget surveys. The former should ideally build on the latter, but this is seldom the case. There are major differences between the two measures of total private consumption. The household budget survey in general gives lower over all figures. This is important to be aware of when combining the two types of accounts.

Although the papers main objective is to present the results of simulations on an increase in the tax on carbon we will discuss these two problems briefly. It is, however, not within the scope of this paper to do any deeper analysis of these issues.

II Frugality or poverty?

In the original design of the project, the distributional analysis was to be done according to income quintiles. The potential regressiveness of fiscal measures was to be evaluated for different income quintiles. This was a natural starting point as most Statistical offices and also the pre 1988 Eurostat compilations published expenditure data with some sort of income groupings.

The (ca) 1988 compilations did not follow this route. Instead it used an expenditure based grouping of households. In the relevant tables it uses Total expenditures per adult equivalent instead of the income groups. The groups are < 0.4, 0.4-0.6, 0.6-0.9, 0.8-1.2, 1.2-1.6 and >1.6 of the mean total expenditures per adult equivalent.

As mentioned above, this approach causes some problems.

-    It makes the idea of finding the economically weaker households and studying the impact
     on them, more difficult. It is definitely easier to argue that a household with a low income
     is economically weak or vulnerable, than to argue that a household that consumes less is
     economically weaker. In order for the argument to hold, one has to assume that there is a
     strong relationship between income and expenditure.

-    There is a possibility that the households that appear weak, by the expenditure
     classification, in fact are frugal, i.e. they do not maximise consumption. This will of course
     always be the case when using expenditure data in itself, but with the classification by
     income groups, the frugal households would be in the right category. The distribution of
     frugal households within each income group is probably not symmetric, but that is another
     issue.

It was possible to use the data from the Swedish expenditure surveys to compare the groupings
on income or expenditure and this enabled at least a tentative picture of the relationships
between the two ways of grouping households. Perhaps Sweden is not a good case given the
tax/transfer schemes and the level of public provision or financing of consumption in place in
the late 80's, but it is an interesting comparison nonetheless.

In the table below, based on the 1992 expenditure survey, households have been tabulated
according to income quintile of disposable expenditure (rows) per adult equivalent and to
expenditure as proportion of mean income (columns) per adult equivalent. The numbers are
rounded percentages and show the distribution over the income categories within a certain
expenditure category.

Table 1 Tabulation of expenditure and income groupings in expenditure survey

		Expenditure group in percent of mean per adult equiv						All	
		< 0.4	0.4-0.6	0.6-0.8	0.8-1.2	1.2-1.6	> 1.6		
		%	%	%	%	%	%	%	n
Income quintile	1	72	49	29	10	7	3	20	725790
	2	20	28	31	19	7	3	20	725149
	3	2	14	23	27	14	6	20	725801
	4	3	6	13	27	29	22	20	726080
	5	2	3	4	18	44	67	20	725495
	Total	100	100	100	100	100	100	100	3628316
	n	78059	504876	828898	1378250	557531	280702	3628316	

It is apparent that the hoped for clustering of households on the diagonal is not present.
Although a large percentage of the households in the lower expenditure groups also are the
households in the lower income groups, the distribution is far from ideal. 5% of the households
in the lowest expenditure groups belong to the top two income categories and 6% of the
households in the highest expenditure group belong to the two lowest income groups.

Looking at the same distribution in a chart, the distributions appear more clearly.

Chart 1 Expenditure groups and income groups

Expenditure vs Income
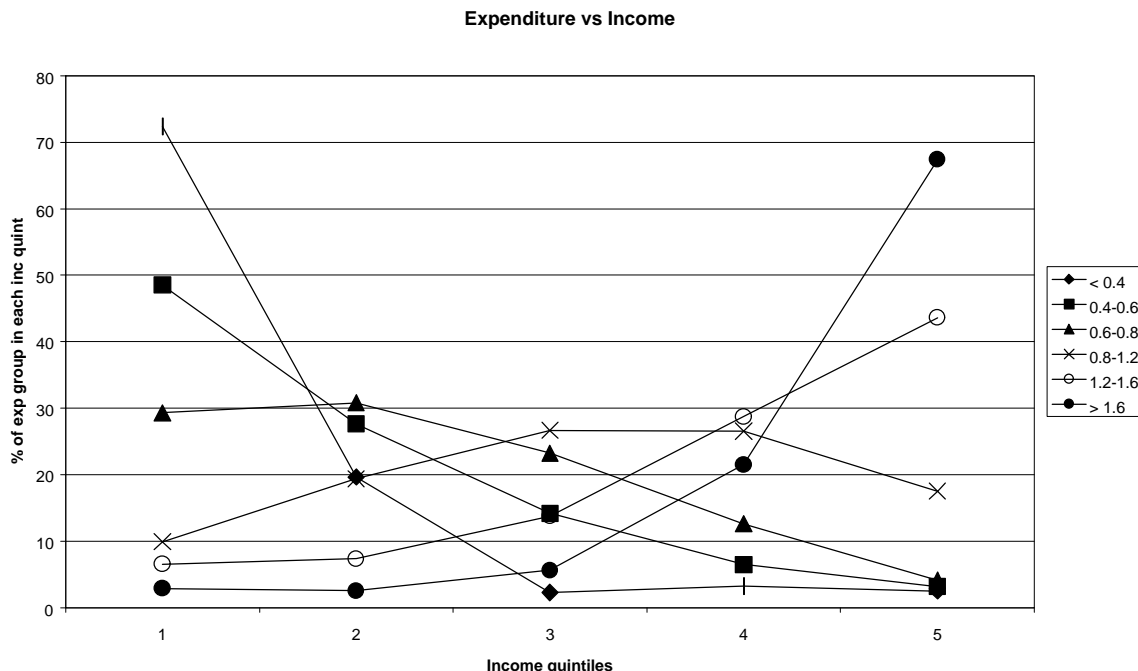
The definition of weak or vulnerable household is not self evident. Other factors than income certainly influence the real or perceived vulnerability of a household. But income is most likely preferable to expenditures, especially if these show a less than hoped for correlation with income groupings.

All in all, the reliance on the expenditures instead of incomes makes it complicated to analyse the distributional effects of fiscal measures as, for one thing, a group of household may (mistakenly?) be classified as poor or weak, when they are actually frugal and may be quite well off. To further complicate matters, although this is less likely in a survey of this scope, it may also be that they are frugal for environmental reasons, i.e. they minimise consumption in general and consumption of ESGS in particular. If this is the case, one could even envision a situation where fiscal instruments could cause a Giffen-type of situation with the effects of the tax working in the wrong direction.

III The model used[2]

The estimation model used is based on the assumption of households having preferences that are weakly separable over time between durable and non durable goods. This means that it is possible to view household demand for non durable goods as a function of prices and total expenditure on non durable goods in itself.

Prices on durable goods will affect the demand for non durable goods through the expenditure share on durable goods, i.e. a constant proportion of expenditure, regardless of the level. The rest is used on non durable goods.

The Linear Almost Ideal Demand system[3] has been used to estimate the demand system for non durable goods. In this model, the expenditure shares for each group of goods is specified as a linear function of the prices (log) and real expenditure (log) on non durable goods.

$$w_i = a_i + \sum_j g_{ij} \log p_j + b_i \log\left(\frac{y}{P}\right) + e_i$$

where

$w_i =$ share of total expenditure on non durable goods that is spent on good i.

$p_j =$ price index for good j

$P =$ price index for non durable goods, approximated by Stones price index
$\log P = \sum_j \overline{w}_j \log p_j$ where $\overline{w}_j$ is the average expenditure share for good j

$y=$ total expenditures on the K different non durable goods

$e_i =$ error term

$a_i, b_i, g_{ij} =$ the estimated parameters

a has been specified as $a_{ih} = \sum_l a_{li} X_{lh}$ in the estimations, where X_h is a vector of household characteristics.

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2)   The model is based on, and to a large extent a replication of, a similar study made by Urban Hansson Brusewitz, Ministry of Finance in Sweden. See Hansson Brusewitz, U "Höjd koldioxidskatt och höjd energiskatt på elektrisk kraft: effekter på hushållens välfärd och konsumtion", in SOU 1997:11 "Skatter, Miljö och Sysselsättning - bilagedelen".
3)   Deaton & Muellbauer "Economics and consumer behavior", Cambridge University Press, 1980

The uncompensated price elasticities in the Slutsky matrix can be written as

$$E_{ij} = \frac{g_{ij}}{w_i} - b_i \frac{w_j}{w_i} - d_{ij}$$

where

$d_{ij} = 1$ if $i=j$ and 0 otherwise

The budget elasticities can be written

$$h_i = \frac{b_i}{w_i} + 1$$

In the estimates, the adding up condition , i.e. $\sum_i a_i = 1, \sum_i b_i = \sum_i g_{ij} = 0$, the homogeneity condition $\sum_j y_{ij} = 0$ as well as the symmetry condition $g_{ij} = g_{ji}$ is imposed.

As stated earlier, the model is estimated on a combination of macro and micro data. The macro data used are the final private consumption by purpose, from the national accounts. These are annual figures for the period 1970-1995. The macro data are used to estimate the price elasticities g. The micro data used come from the 1992 Household Budget Survey (HBS). This is used to estimate the budget shares and gives the base for the distributional analysis.

IV The expenditure data

The micro data

Detailed expenditure surveys has a thirty year history in Sweden. Since the late 60's there has been half a dozen large scale expenditure surveys that cover some 200 goods and services. The methods and instruments used have varied slightly over the years, depending on specific purposes. For instance, the inclusion of detailed surveys of the expenditure on food stuffs, more or less emphasis on distribution within households in clothing expenditure, etc.

The 1992 survey was the last (so far) full scale survey covering a year and with a large sample. As of 1995 the survey is supposed to be carried out on a continuos basis with a reduced

sample of app. 200 households per month participating.[4] The move to an annual survey is in line with the development in the majority of the member states.

The modelling is based on the 1992 HBS[5]. This survey was based on a sample of 6000 households of which 3806 participated in all moments of the survey. They kept an expenditure log of everything purchased over a 4 week period. In addition to this there is an interview in which background data on the household is collected, as well as data collected from registers, mainly on incomes.

Using a combination of micro and macro data it would, of course, be an advantage if the results obtained in the two sources in terms of total expenditure/consumption were roughly the same. It is furthermore something that would be expected as one of the original expressed aims of the HBS was to provide a basis for compiling the private consumption part of the national accounts.

HBS and private consumption in the national accounts

Ideally, a yearly HBS would be used to assist the national accounts on:

-    the composition of private consumption, i.e. the levels of each commodity group.

-    parts of the industry-commodity matrix, that is used to allocate industry output (e.g. from sales data) to goods and services purchased.

-    the first forecasts of the private consumption part of GDP, i.e. on the changes for the 1:st quarter.

-    subsequent revisions of GDP and private consumption.

Private consumption, and the different GDP components are basically calculated on the changes in the period. This means that the absolute levels of total expenditure as it appears in the HBS is not really of any greater interest. Basically, the incremental approach is one way of constructing the accounts in order to achieve consistency in the series.

In some countries, the HBS is seen as a source for independent estimates of the levels of private consumption. This is however somewhat controversial as the levels in the national accounts reflects the base levels set a long time ago as well as the skills in establishing the growth rates in a single period. Differences in the levels predicted from the accounts and from HBS will differ by default and this is probably seen as an argument not to put to much of an emphasis on the totals and levels of the HBS. There is of course no way of concluding that one estimate is more true than the other - although the national accounts figures are consistent with other economic indicators.

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4)   The HBS was temporarily discontinued in late 1997 due to decreasing response rates. The design is being changed to alleviate this and the new HBS will probably be launched 1999.

5)   Statistics Sweden "Hushållens Utgifter 1992"

The final consumption in the national accounts (NAPC) is based on many sources - of which the HBS is one, although insignificant, source. The last time the HBS was put to any greater use in the national accounts in Sweden, was when using the 1978 survey to reset the levels of private consumption in the early 80's. Apart from a few exceptions, these are still the base levels used in the national accounts.

It is well known that NAPC and total expenditures as they come out in the HBS differ. According to a survey by Eurostat, the discrepancy for total consumption is around 30%, of which 2/3 comes from differences in population, concepts and definitions and the rest comes from underreporting of different sorts.[6] The differences for some countries are presented in the table below.

Table 2 Discrepancies between HBS and national accounts data

Country	HBS data %	Popul. Adj. %	Def. & concept adj. %	Imputed rent adj %	NA estimate %
Austria	77	91	91	99	100
France	64	66	77	86	100
Germany	67	77	79	87	100
Italy	63	67	74	82	100
UK	72	75	81	90	100

The differences in population stems from the fact that HBS survey private households. This means that it does not include persons living in institutions or foreign tourists. Both included in the NAPC. It also comes from the differences in the age groups surveyed in the HBS. In Sweden there is an age limit of 75 in the HBS while the NAPC covers consumption of all, regardless of age.

The differences in definitions and concepts are due to the different treatment of a series of expenditure types. Among these are:

Consumption of household own production, benefits in kind, insurance, hiring/leasing, gifts and transfers, equipment and clothing needed for work, capital expenditure etc.

The major part of the difference in concepts and definitions has to do with the imputation of the rent of housing.

An adjustment of the HBS to cater for these differences, will bring the totals closer, but there will still be discrepancies in different goods categories. In the table below, the discrepancies for single goods can range from 20% up to 140% comparing other goods n.e.c for Italy and Austria. Or between 40% and 200% looking over all goods in the Austrian expenditure survey.

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6)   This section is based on "Task force on the use of Household Budget Surveys for National Accounts - Final report", Eurostat, September 1996

Table 3 Break down of the expenditure discrepancies

ITEMS	Aus %	Fra %	Ger %	Ita %	UK %
Bread and cereals	100	104	93	124	100
Meat and fish	88	82	85	100	100
Milk, cheese, eggs, oil, fats	89	79	131	110	100
Fruit, vegetables, potatoes	74	106	135	63	100
Sugar	200	100	91	100	100
Other food, including preserves	121	79	78	100	57
Non-alcoholic beverages	122	97	110	100	100
Alcoholic beverages	71	66	67	70	60
Tobacco	86	56	54	92	64
Clothing	100	86	85	58	90
Footwear	100	77	91	78	100
Gross rent	95	100	95	100	100
Fuels and power	129	95	121	100	107
Furniture, fixtures, hh.textiles	102	82	82	53	100
Households' appliances	111	74	123	67	40
Glassware	67	87	52	140	133
Domestic, home care services	122	94	78	53	100
Pharmaceutical products	50	100	85	83	50
Therapeutic appliances	100	100	36	100	100
Medical services	42	100	75	104	100
Hospital services	45	100	81	57	100
Personal transport equipment	111	104	81	70	124
Operation on pers.transp. equip.	85	62	86	150	103
Transport services	73	75	57	38	50
Communication	96	94	82	108	88
Radio and television sets, hi-fi	167	72	81	65	83
Books, newspapers, magazines	155	71	67	87	100
Education	167	99	66	43	83
Entertainment, recreat. services	92	127	49	92	77
Personal care and effects	160	63	82	76	100
Restaurants, cafe's and hotels	106	79	93	72	100
Other goods n.e.c.	139	49	95	19	100
Financial services	75	44	77	60	59
Other services n.e.c.	88	87	123	43	43
TOTAL	99	86	87	82	90

For the goods most of interest here, i.e. goods like operations on personal transport equipment, transport services, fuels and power, etc., it is apparent that the discrepancies vary from over- to underestimation. Transport services are all lower while fuels and power are mostly overestimated.

In the case of Sweden the comparison between the 1992 HBS, adjusted for population differences, and the national accounts show the following pattern for some of the relevant goods:

Table 4 Comparisons for some goods for Sweden

Goods category	HBS % of nat accounts
Household energy	76
Petrol	103
Other cost for personal transp equip	116
Transportation	40

One of the problems with these differences is that the expenditure shares estimated from macro and micro data will come out differently. The expenditure share for transportation (i.e. public transports) will for instance be much lower than the expenditure share for the same commodity in the macro data, especially using the unadjusted figures from the HBS. The same applies to household energy (i.e. public transports) expenditure category. The expenditure shares of Petrol and other costs for personal transportation (that has been aggregated into Car Maintenance in the model) will be higher in the micro data.

V The estimated model

The goods in the model

The demand system has been estimated for the following 12 categories of non durable goods:

Food

Alcohol

Tobacco

Leisure/Culture, which includes all leisure goods, charter tours, hotels, restaurants, private education entertainment etc.

Literature, i.e. books and magazines

Publ transp/communication, i.e. travel by rail, air or water, telecommunication, mail

Car maintenance, i.e. fuel, repairs, parking etc

Electricity

Household fuel, i.e. gas and other fuels

Household Services, i.e. repairs, washing and cleaning, child care, hair dressers etc.

Cloth and shoes

Other, includes financial services and health care

This is not an ideal aggregation. One would probably have wished for a better disaggregation of the transports and some of the components now in the leisure/culture categories. The main reason for choosing this classification is one of quality of data. Initial tests with more disaggregated classifications gave very poor estimates. Another reason is, of course, comparability with previous estimates.

The estimated elasticities

The uncompensated price elasticities, evaluated at the mean expenditure shares (in the macro data), are by and large of the expected sizes and signs. The own price elasticities are marked on the diagonal of the split matrix. The only own price elasticity with a positive sign is that of literature, which is a notoriously difficult commodity in the national accounts.

The own price elasticity of car maintenance, i.e. mainly petrol, is -0.06. This means that a 1% increase in the price will reduce the demand by 0.06%, i.e. that petrol is a very price insensitive good. This elasticity is lower than those produced with similar methods in other analysis where it usually is set to above 0.1 with a long run elasticity closer to the one found in this study. A low elasticity is also given for household energy, -0.01.

The higher own price elasticities are found for leisure (-1.144) and clothing (-1.095).

Alcohol has an unexpectedly high own price elasticity of -1.033.

Table 5 The uncompensated price elasticities

		Demand for					
		Food	Alcohol	Tobacco	Leisure	Litterature	Publ transp
	Food	-0.640	-0.793	0.247	-0.198	0.084	-0.090
	Alcohol	-0.111	-1.033	-0.428	0.226	0.054	0.025
	Tobacco	0.027	-0.314	-0.268	-0.059	-0.167	0.017
	Leisure	0.090	1.280	-0.162	-1.144	-0.680	-0.336
Price of	Litterature	0.018	0.034	-0.133	-0.105	0.147	-0.088
	Publ transp	-0.031	0.009	0.032	-0.199	-0.268	-0.337
	Car maint.	0.104	-0.486	-0.308	-0.154	0.191	0.122
	Electricity	-0.055	0.090	0.135	-0.042	0.161	0.130
	Househ fuel	-0.040	0.105	0.060	-0.062	-0.110	-0.007
	Househ Services	-0.026	0.049	0.043	-0.005	-0.315	0.059
	Cloth	0.275	-0.091	-0.087	-0.061	0.225	-0.303
	Other	-0.149	0.255	0.356	0.048	-0.266	0.395

		Demand for					
		Car maint.	Electricity	Househ fuel	Househ Services	Cloth	Other
	Food	0.161	-0.375	-0.829	-0.392	0.481	-0.557
	Alcohol	-0.180	0.120	0.213	0.100	-0.059	0.101
	Tobacco	-0.091	0.110	0.066	0.052	-0.052	0.091
	Leisure	-0.103	0.021	-0.648	0.147	-0.056	0.228
Price of	Litterature	0.045	0.124	-0.168	-0.372	0.044	-0.074
	Publ transp	0.044	0.235	-0.100	0.159	-0.267	0.227
	Car maint.	-0.068	-1.042	0.092	0.125	-0.470	-0.022
	Electricity	-0.355	-0.251	0.578	-0.105	0.240	-0.186
	Househ fuel	0.027	0.308	-0.011	-0.122	-0.061	-0.041
	Househ Services	0.023	-0.054	0.135	-0.491	0.103	-0.108
	Cloth	-0.372	0.761	-0.357	0.554	-1.095	-0.214
	Other	0.006	-0.428	-0.255	-0.456	-0.232	-0.572

Car maintenance and public transports are substitutes, as the cross price elasticities are positive. A 1% increase in car maintenance price will increase the demand for public transport by 0.1%.

The same relationship exist between household fuel and electricity, where a 1% increase in the price of electricity will increase the demand for household fuel by 0.578%.

Turning to the budget elasticities (evaluated at the mean expenditure shares from the micro data) there is a clear pattern with Alcohol, Leisure, Household services, Clothing and Other commodities being seen as luxuries (i.e. with a budget elasticity of > 1). Food, car maintenance, Electricity and Household fuel are necessities with an elasticity of <1. The estimation shows Tobacco to be a necessity in these terms.

Table 6 The household budget elasticities

Food	Alcohol	Tobacco	Leisure	Literature	Publ transp	Car maint.
0.578	1.905	0.481	1.562	0.857	0.902	0.609

Electricity	Househ fuel	Househ Services	Cloth	Other
0.337	0.22	1.478	1.323	1.543

The elasticities are evaluated at the mean expenditure shares and are interpreted as the relationship between a 1% increase in expenditure on non durable goods and the percentage change in demand for the different groups of goods.

The micro data also allows for a grouping of the household according to different household characteristics, such as demographics, socio-spatial dimensions, housing etc.

Looking at the share for food expenditure this is positively related to the presence of smaller children while expenditure on alcohol and tobacco is negatively related to the presence of smaller children.

Living in a big city decreases the expenditure share for car maintenance and for electricity, while living in the rural north increases these expenditures.

Living in a rented apartment decreases the expenditure share for electricity and car maintenance while living in a owner occupied dwelling increases the shares expenditure shares.

The expenditure share for car maintenance decreases with increasing socio-economic ranking and that of clothing and leisure goes the other way.

It is well worth noting that the expenditures shares, as they come out of the 1992 HBS, are not very regressive in the ESGS - especially when viewing them by income quintiles.

VI The idea in the simulations

The basic idea in the simulations is to use the estimated model to predict an expenditure system for the 1995 tax system.[7] This is then used as a baseline to simulate the effects for different household types of a tax increases on CO2. In one scenario without any compensation, and in another, with compensation in the form of a decrease in the VAT, that is set to be revenue neutral in terms of the total revenue collected.
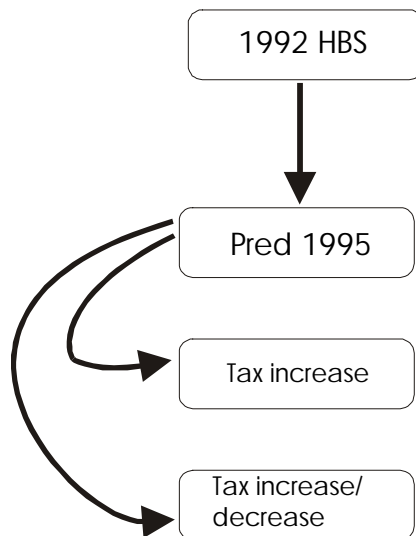
The changes in prices through the changes in the tax system between 92 and 95 for the aggregated expenditure categories is handled in the following way.

$$\frac{\Delta p_i}{p_i^{0}} = \sum_{k=1}^{K_i} w_{ik} \frac{t_{ik}^1 + \mathrm{t}_{ik}^1 + t_{ik}^1 \mathrm{t}_{ik}^1 - \left(t_{ik}^0 + \mathrm{t}_{ik}^0 + t_{ik}^0 \mathrm{t}_{ik}^0\right)}{1 + t_{ik}^0 + \mathrm{t}_{ik}^0 + t_{ik}^0 \mathrm{t}_{ik}^0}$$

where:

$K_i =$ the number of homogenous goods, from a tax point of view, in expenditure group i

$w_{ik} =$ expenditure share for good k in expenditure group i.

$t_{ik}^m =$ VAT rate for good ik (the rate on the price excluding the VAT). M=0 for 1992 and 1 for 1995

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7)   As this study was initiated in 1996/97 and the basic data was collected then.

$t_{ik}^m =$ Tax rate for good *ik* (some taxes are recalculated as value relate taxes although they are in actual case unit taxes) the rate is calculated as the rate on the price excluding the tax. M=0 for 1992 and 1 for 1995

The prices in the 1992 system is set to 1 which means that the price for good *i* in the 1995 tax system is $1 + \dfrac{\Delta p_i}{p_i^0}$. These new prices are also used to calculate a new price deflator for total expenditures on non durable goods.

The value related taxes are calculated in the following way

$$t_{ik} = \frac{r_{ik}(1 + t_{ik})}{1 - r_{ik}(1 + t_{ik})}$$

where

$$r_{ik} = \frac{t_{ik}}{(1 + t_{ik})(1 + t_{ik})}$$

For alcohol and tobacco r_{ik} has been calculated as the relation between the tax revenues and the reported total expenditures/sales. The following table lists some of the tax rates for relevant goods. The CO_2 tax was 0.34 Sek per Kg in 1995.

Table 7 Tax rates and changes between 92 and 95

	1992		1995		
	Of prod price	Of cons price	Of prod price	Of cons price	Of which CO2 tax
Light fuel for heating	0.374	0.878	0.379	0.985	0.620
Diesel	0.360	0.820	0.510	1.760	0.669
Petrol (unleaded)	0.471	1.434	0.519	1.861	0.364
Household electricity	0.128	0.191	0.144	0.220	
Alcohol	0.410	1.060	0.38	0.920	
Tobacco	0.460	1.353	0.459	1.344	

The unreduced VAT rates was 25% for the 92-95 period. In 1992 there was a reduced VAT rate of 18% on food, personal transports, hotel and restaurants. In 1995 the VAT for food was 21% and on Hotel and personal transports, 12%.

The tax exempt goods in the 1992-95 period were, among other, apartment rents, housing interests, insurance premiums, health care, education and social care, some cultural goods and services, daily papers, prescribed medicine and packaged holidays travels.

The taxes paid by the household in VAT and other consumption taxes (*OT*) are calculated in the following way, where the expenditure shares within each expenditure category (incl. durable goods) is set at the 92 level.

$$VAT = \sum_{i=1}^{K+1} \sum_{k=1}^{K_i} \frac{t_{ik}^m}{1+t_{ik}^m} w_{ik}^0 y_i^m$$

$$OT = \sum_{i=1}^{K+1} \sum_{k=1}^{K_i} \frac{t_{ik}^m}{\left(1+t_{ik}^m\right)\left(1+t_{ik}^m\right)} w_{ik}^0 y_i^m$$

for m= 0,1

Using the calculated baseline for 1995, a doubling of the carbon tax is introduced. This will produce a new expenditure mix that will change the amount different households pay in taxes.

The same procedure is repeated, but with a compensating tax decrease in the VAT. The level of this decrease is set to produce roughly the same tax revenues as before the introduction of the raised carbon tax.

The evaluation in terms of the effects for the household is done through the taxes paid and the implicit tax rate for different household types as well as through an estimate of the compensated variation, i.e. the increase in income that different household types would need to return to the level of welfare they had before the change in taxes. The larger the compensated variation, the more the households lose on the tax reform.

The calculation of the compensation amount that would be needed, as a lump sum transfer, in order to for the household to retain its pre-tax welfare is calculated by looking at the expenditure that the household would need with the new set of prices (*p*) to reach the utility level they had in 95 with 95 prices - $CV = E\left(p, V\left(p_{95}, y_{95}\right)\right)$.

Using a 2:nd order Taylor approximation this can be written as:

$$CV \approx x_c\left(p_{95}, V_{95}\right)\left(p - p_{95}\right) + 0.5 * \left(p - p_{95}\right)' \frac{dx_c}{dp}\bigg|_{p_{95}} \left(p - p_{95}\right)$$

where x_c is a vector of Hicksian demand functions.

$x_c\left(p_{95}, V_{95}\right)$ can be calculated as the ratio between expenditures and prices over each goods category under the 95 tax system.

$$\frac{\mathrm{d}x_c}{\mathrm{d}p}\bigg|_{p_{95}} = \left[S_{ij} \right]$$ is a matrix of compensated own- and cross price elasticities that are calculated

in the Linear Almost Ideal Demand system as:

$$S_{ij} = \begin{cases} \left(g_{ii} + w_{i,95}^2 - w_{i,95} \right) \dfrac{y_{95}}{p_{i,95}^2} & i = j \\[2ex] \left(g_{ij} + w_{i,95} w_{j,95} \right) \dfrac{y_{95}}{p_{i,95} p_{j,95}} & i \neq j \end{cases}$$

VII Results of the simulation

In the simulation results below, the effects of the increase in the carbon tax, as such, are separated from the case where the increase in the carbon tax is offset by a decrease in VAT. The decrease in VAT is just above 6%, or roughly 1.5 percentage points of the full VAT.

The uncompensated increase in the Carbon tax increases the indirect tax paid per adult equivalent and the implicit tax rate, for all groupings. There are however differences.

Looking at the effects over the income per adult equivalent quintiles, the already regressive implicit tax rate get more regressive as the percentage point increase for the higher quintiles are lower than that for the lower quintiles.

The loss in real income, the Compensated Variation, ranges from just over 2000 SEK per household in the lower quintiles to close to 2500 SEK for the highest quintile. Setting this in relation to the expenditure per adult equivalent in the different groups, the lower quintile lose over a percent of their expenditure per adult equivalent in terms of real income while the highest quintiles loses below 1 percent.

Looking at the Eurostat classification according to relation to the mean expenditure per adult equivalent, the distribution becomes more extreme. The implicit tax rate ranges from close to 20% down to just under 14% in the base case. With the increase in the carbon tax this difference is increased with the lowest expenditure groups getting an increase of .8 percentage points and the highest group only getting a .4 percentage point increase.

The losses in real income, measured in relation to their expenditure per adult equivalent show substantial differences. It is almost a 100% difference between the lowest and the highest group.

Table 8 Results from simulation with uncompensated increase in Carbon Tax

		Indir tax / ad equiv SEK	Impl tax rate %	Change in indir tax/ ad equiv SEK	Change in impl tax rate % points	Real Inc loss SEK	Real inc loss/Exp %
Income Quint							
	1	12935	17.53	462	0.63	2055	1.102
	2	14910	16.53	514	0.57	2232	1.029
	3	16590	16.03	573	0.56	2197	1.003
	4	20231	16.32	680	0.56	2284	1.011
	5	24752	15.22	847	0.53	2469	0.956
expenditure per adult equiv in relation to the mean							
	< 0.4	7621	19.83	317	0.81	1485	1.355
	0.4-0.6	10683	18.28	411	0.69	1922	1.258
	0.6-0.9	13312	16.84	495	0.62	2012	1.059
	0.8-1.2	17928	16.15	619	0.55	2324	1.006
	1.2-1.6	23698	15.25	792	0.49	2509	0.903
	>1.6	31866	13.90	1037	0.43	2719	0.748
Singles with num of children							
	0	21081	17.90	818	0.69	1382	1.183
	1	19373	17.38	750	0.68	2003	1.145
	2	14186	17.02	480	0.61	2127	0.982
Cohab with num of children							
	0	21919	16.12	797	0.61	2191	1.074
	1	17213	16.25	541	0.53	2527	0.999
	2	14303	15.72	440	0.50	2558	0.919
Regions							
	Big cities	18902	15.24	656	0.54	2137	0.890
	Larger towns	17481	16.43	600	0.57	2267	1.039
	South midl	17376	17.05	596	0.59	2303	1.108
	North	16963	16.76	589	0.58	2296	1.073
	Rural north	18348	17.90	611	0.59	2413	1.165

Looking at household types, both singles and couples with children are less hurt by the increase than those without children. The implicit tax rates for singles is generally higher than for couples. The loss in real income in relation to the expenditure per adult equivalent is also higher for singles, with or without children, than for couples with or without children.

The regional perspective indicates that households in the rural north of Sweden will lose more from the increased tax than households in the south. Households in the big cities are best off with a real income loss in relation to expenditure that is well below 1 percent.

In the table below, the results from the simulation with a reduction in the VAT is presented.

The general picture is that the decrease in the VAT benefits those that spend most. The households that actually benefit, in terms of having to pay lower taxes over all, are those in the highest two expenditure groups. This effect does not show up in the income quintiles. There is an increase in the implicit tax rate for most groups, regardless if one look at them from income, expenditure, demographics or a regional perspective.

It is well worth noting the differences in results depending on the choice between expenditure or income grouping of the households. The expenditure grouping gives a sharper regressive effect than the income grouping. Maybe Sweden is a bad case for making these kinds of comparisons, but it is probably wise to interpret the effects received when using the expenditure groupings, with caution.

Table 9 Results from simulation with compensated increase in Carbon Tax

		Indir tax / ad equiv SEK	Impl tax rate %	Change in indir tax/ ad equiv SEK	Change in impl tax rate % points	Real Inc loss SEK	Real inc loss/Exp %
Income Quint							
	1	12935	17.53	29	0.05	214	0.311
	2	14910	16.53	19	0.03	241	0.285
	3	16590	16.03	19	0.03	258	0.280
	4	20231	16.32	26	0.03	319	0.289
	5	24752	15.22	32	0.04	367	0.280
expenditure per adult equiv in relation to the mean							
	< 0.4	7621	19.83	66	0.17	178	0.473
	0.4-0.6	10683	18.28	73	0.12	269	0.462
	0.6-0.9	13312	16.84	55	0.07	239	0.305
	0.8-1.2	17928	16.15	36	0.02	311	0.282
	1.2-1.6	23698	15.25	-5	-0.02	336	0.218
	>1.6	31866	13.90	-61	-0.04	191	0.099
Singles with num of children							
	0	21081	17.90	131	0.12	446	0.393
	1	19373	17.38	82	0.09	377	0.350
	2	14186	17.02	-19	0.01	129	0.186
Cohab with num of children							
	0	21919	16.12	83	0.09	405	0.362
	1	17213	16.25	-20	0.01	231	0.277
	2	14303	15.72	-41	-0.02	150	0.206
Regions							
	Big cities	18902	15.24	6	0.03	196	0.189
	Larger towns	17481	16.43	26	0.04	286	0.306
	South midl	17376	17.05	40	0.04	342	0.355
	North	16963	16.76	43	0.05	319	0.332
	Rural north	18348	17.90	36	0.04	381	0.391

The compensation through VAT increases the relative loss for childless singles and couples in relation to those with children as they have relatively high increases in their implicit tax rate.

The loss in real income is, of course, smaller but still visible. The regional distribution of these losses goes increasingly in favour of the big cities.

The interesting question is how these welfare losses due to the price changes are counterbalanced by other effects. It is not possible to analyse the over all effects in the economy within the present framework, i.e. employment effects and efficiency gains are outside the partial equilibrium analysis.

However, the main purpose of the carbon tax is to reduce emissions. Naturally, this is an expected benefit that should be set against the welfare losses appearing in the analysis.

In the following table the changes in total volumes for the most relevant goods are presented.

Table 10 Changes in expenditure, prices and volumes in the two scenarios

	Publ transp %	Car maint. %	Househ fuel %
Uncompensated			
Expenditure	2.38	6.12	5.44
Prices	2.49	8.26	6.12
Volume	-0.11	-1.98	-0.64
Compensated			
Expenditure	2.76	6.34	5.52
Prices	1.80	7.14	5.54
Volume	0.94	-0.75	-0.02

The close to 2% reduction in car maintenance (to a large extent petrol) in the scenario without a compensating VAT reduction will produce a reduction by app. 90 million litres of petrol. The question is how large a reduction in CO2 emissions this, and other reductions in fuels, will produce, both indirectly in the refining process and directly in the use of the fuel.

VIII Concluding remarks

The analysis of the distributional effects of an increase in the tax on CO_2 gives the expected results. A environmental fiscal reform designed the way presented here will have negative distributional effects. Compensating these effects by offsetting reductions in VAT, is not really possible. This is, of course, not an argument that it is impossible to compensate specific groups that lose in the reform. It is more of an argument for being specific as to how one defines these groups on the one hand, and the need for targeted compensations rather than depending on general measures such as lowering VAT, on the other.

Many factors have been left out of the analysis, as this is a demand-side analysis. The effects on the supply side of the economy could potentially be offsetting, although results using CGE-models for Sweden are not very optimistic on this point[8].

On a methodological note, this and other similar analysis points to the possibilities of making more use of micro data for analysing sustainability questions from a distributional point of view. To most readers, this kind of analysis will always be a black box that turns out results that may theoretically correct but empirically impenetrable. That is probably inescapable.

However, using these types of simulations will help in addressing the distributional questions at issue. The results may be debated but the focus of the debate will be on distributional issues otherwise neglected.

Much more could probably be done if the micro data used were more easily accessible. With more independent estimations and simulations the distributional questions could be brought further into the policy arena. In a European Community perspective, the comparability issues will always be problematic but also something that is at the heart of much statistical work in the community. Harmonisation is usually at the top of the agenda, and these are problems that should be possible to solve, more or less satisfactory. The present design of the compilation of expenditure surveys, with the expenditure groupings replacing the income groupings, is unfortunately an example of a less satisfactory attempt.

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8)   Harrison & Kriström "Carbon taxes in Sweden", in Skatter, miljö och sysselsättning - bilagedel", SOU 1997:11.