The income-pollution relationship and the role of income distribution

Evidence from Swedish household data†

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Abstract

The main purpose of this study is to analyze the relationship between pollution and income at household level. The study is motivated by the recent literature emphasizing the importance of income distribution for the aggregate relation between pollution and income. The main findings from previous studies are that if the individual pollution-income relationship is non-linear, then aggregate pollution for, say, a whole country, will depend not only on average income, but also on how income is distributed. To achieve our objective we formulate a model for determining the choice of consumption of goods in different types of household. Furthermore we link the demand model to emission functions for the various goods. The theoretical analysis shows that without imposing very restrictive assumptions on preferences and the emission functions, it is not possible to determine *a priori* the slope or the curvature of the pollution-income relation. The empirical analysis shows that, given the model used, the pollution-income relation has a positive slope in Sweden and is strictly concave for all three pollutants under study (CO_2, SO_2, NO_x), at least in the neighborhood of the observed income for an average household. Further, the results show that the curvature of the relation differs between different types of households. We also show that altering the prevailing income distribution, holding average income constant, will affect aggregate emissions in the sense that an equalization of incomes will give rise to an increase in emissions. One implication is then that the development of aggregate pollution due to growth depends not only on the income level, but also on how growth is distributed.

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1. Introduction

The main purpose of this paper is to investigate the relationship between pollution and income at household level. The analysis is motivated by the recent literature emphasizing the importance of income distribution for the aggregate relation between pollution and income (see for example Stern, 1998, Torras & Boyce, 1998, Heerink et al. 2001, and Huang, 2005). For example, Heerink et al. (2001) showed that if the relationship between pollution and income is non-linear at the individual level, the aggregate pollution-income relationship will depend on income distribution. Thus, if the individual relationship is non-linear, omitting income distribution from the aggregate analysis will produce biased results. However, no studies to date have used a structural approach to investigate the way in which individual (or household) pollution changes with economic growth. The empirical analyses available are mostly reduced form aggregate types of studies that are unable to encompass tests of how income changes affect individual pollution via changes in the real consumption basket. Here we will address the issue on the household level by estimating a demand model for Swedish households which is directly linked to emissions of sulfur, nitrogen oxides, and carbon dioxide. We will then use the result to illustrate how changes in income distribution affect aggregate emissions of CO_2, SO_2 and NO_x in Sweden.

The relationship between environmental performance and economic development has been the subject of discussion for a long time. One line of argument is that economic growth inevitably leads to more emissions and ultimately to degradation of the natural environment (Meadows *et al.* 1972, 1992). Another is that economic growth is necessary for improving the environment. This latter argument can be found in, for example, Grossman and Krueger (1991, 1995), who showed that for some emissions there appears to be an inverted U-shaped relationship between emissions and income. Countries with relatively low income appear to have relatively low emissions, middle income countries have relatively high emissions, and high income countries tend to have relatively low emissions. Thus the conclusion would be that as a poor country gets richer, emissions rise. However, when income passes a certain critical level emissions start to fall. This inverted U-shaped relationship between emissions and income has been dubbed the environmental Kuznets curve (EKC).

The discovery of this potential relationship triggered substantial research efforts in this area, theoretical as well as empirical. The theoretical literature has focused mainly on the assumptions required with respect to technology/preferences and emissions (Lopez, 1994;

Selden and Song, 1995; McConell, 1997; Andreoni & Levinson, 1998; Kriström 2000) for an EKC relationship to exist. However, the bulk of the empirical literature differs substantially from the theoretical. In general the empirical models are a reduced form type using cross-country data over relatively short time periods. A typical empirical model specifies emissions as a nonlinear function of income, income distribution, and a number of country specific characteristics such as population density, trade intensity and openness to trade (see Grossman and Krueger, 1991, 1995; Stern, 1998).[1] One conclusion from these studies is that openness seems to be beneficial to the environment.[2] Another conclusion from more recent studies is that using mean income may lead to biased results due to skewed income distributions. Instead the use of the median income is proposed (see Stern, 1998). According to Torras & Boyce (1998) and Bimonte (2002) an increase in equity, measured by the Gini coefficient, shifts the EKC curve leftwards, implying a turning point at a lower income level. Heerink et al. (2001) on the other hand get the opposite result for several environmental indicators analyzed on a cross-section of different countries. Thus, according to their results there may be a trade off between income equality and environmental quality. More importantly they conclude that this effect may be due to a strictly concave pollution-income relation at the individual level.

The rest of this paper is structured as follows. In section 2 we provide a discussion of how the household pollution-income relation may affect the aggregate relation and lay out the basis for our structural model. In section 3 and 4 we discuss in greater detail how consumption patterns and emissions are linked, as well as providing the modeling framework and a description of the data used in the analysis. Results from the econometric model are presented in section 5, along with an empirical analysis of the pollution-income relationship. The paper ends with some concluding remarks in Section 6.

2. Pollution and income

It is obvious that consumption will give rise to emissions of various pollutants. This in turn implies that any change in prices, income, or preferences that affects the consumption bundle will also have an affect on pollution. Essentially, there are two possible effects; an income

[1] It may be questioned whether models of this kind should be denoted "reduced form" models. The reason is that a right hand shock (policy or other) affecting pollution probably affects income as well.

[2] For a survey of the empirical literature in this area, see Stern (1998), or Panayotou (2000).

effect and a substitution effect. Thus we would in principle be able to express pollution from a specific household as:

$$E_i = g(x_1(\mathbf{p}, y_i), x_2(\mathbf{p}, y_i), \ldots, x_k(\mathbf{p}, y_i)) = f(\mathbf{p}, y_i), \quad i = 1, \ldots, n \qquad (1)$$

where E_i is emissions of the pollutant from household i, $x_j(\mathbf{p}, y_i)$ is consumption of good j as a function of prices $\mathbf{p} = [p_1, p_2, \ldots, p_k]$ and income y_i. g is the function that maps consumption to emissions.

Thus, a change in income for a household will result in a change in emissions, E, via a change in the composition of the consumption basket. Aggregating over the n households gives:

$$\overline{E} = \frac{1}{n}\sum_{i=1}^{n} f(\mathbf{p}, y_i) = f(\mathbf{p}, \overline{y}) + \frac{1}{n}\sum_{i=1}^{n}\left[f(\mathbf{p}, y_i) - f(\mathbf{p}, \overline{y})\right], \qquad (2)$$

where $\overline{y} = (1/n)\sum_{i=1}^{n} y_i$, i.e. the average income per capita.

The second term on the right hand side of (2) indicates the degree of non-linearity of the household reduced form function f. Thus, if the household pollution-income relationship is non-linear, income distribution, as well as the income level, matters for aggregate pollution. Suppose that f is a strictly convex function. Then the second term in (2) is positive which means that a redistribution of income towards equalization would reduce the value of the second term, and hence also average emissions per capita (see Figure 1a). The opposite holds true if f is strictly concave, an increase in equality would increase aggregate emissions (see Figure 1b).

An illustration is provided in Figure 1. Consider two households, one poor (y_1) and one rich (y_2). Given income distribution y^1 we see that average emissions are $\overline{E}_1$. The effect on pollution of a redistribution from the rich to the poor, resulting in income distribution y^2, thus depends on the curvature, as can be seen from Figures 1a and 1b.

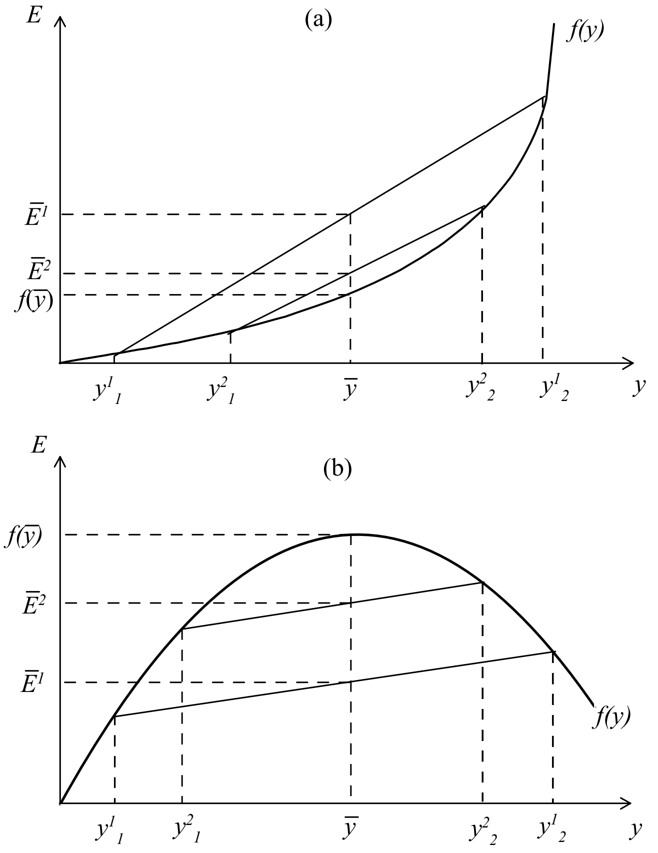

Figure 1. Household and aggregate emissions.

From equations (1) and (2) it is clear that we cannot determine the curvature of the household pollution-income relation *a priori* since the curvature depends not only on the relation between consumption and pollution, but also on how consumption is affected by a change in income. The slope of the pollution-income relation for individual i can be written as

$$\frac{\partial f(\mathbf{p}, y_i)}{\partial y_i} = \sum_{j=1}^{k} \frac{\partial g}{\partial x_j} \frac{\partial x_j(\mathbf{p}, y_i)}{\partial y_i} \ , \quad i = 1, \ldots, n \tag{3}$$

Equation (3) can be written in terms of income elasticities and budget shares (weighted by prices) as:

$$\frac{\partial f(\mathbf{p}, y_i)}{\partial y_i} = \sum_{j=1}^{k} \frac{\partial g}{\partial x_j} \frac{1}{p_j} \varepsilon_{ij} s_{ij}, \quad i = 1, \ldots, n \tag{4}$$

where $\varepsilon_{ij} = \frac{\partial x_{ij}(\mathbf{p}, y_i)}{\partial y_i} \frac{y_i}{x_j}, \ s_{ij} = \frac{p_j x_{ij}}{y_i}$

PROPOSITION 1

Given that $\partial g/\partial x_{ij} \geq 0$ for all j, it follows that a sufficient condition for a positive pollution-income relationship is that all goods are normal goods, i.e. if all goods have a non-negative income elasticity.

Proof:

Follows directly from equation (4), and that $s_{ij} > 0$ and $p_j > 0$.

It should be pointed out however that this is not a necessary condition. Thus, given that $\partial g/\partial x_{ij} \geq 0$ for all j, a necessary condition for a downward-sloping relationship is that at least one good is an inferior good.

The curvature of the pollution-income relation can then be expressed as (suppressing the household index i):

$$\frac{\partial^2 f}{\partial y^2} = \sum_{j=1}^{k} \frac{1}{p_j} \left[\left(\frac{\partial^2 g}{\partial x_j^2} \frac{\partial x_j}{\partial y} s_j + \frac{\partial g}{\partial x_j} \frac{\partial s_j}{\partial y} \right) \varepsilon_j + \frac{\partial g}{\partial x_j} \frac{\partial \varepsilon_j}{\partial y} s_j \right] \qquad (5)$$

From (5) we see that the curvature depends on the shape of the pollution function g, as well as the income elasticity for each good, and the budget shares.

PROPOSITION 2

If $(\partial g/\partial x_1)/(1/p_1) = \ldots = (\partial g/\partial x_k)/(1/p_k) = \Phi > 0$, and $\partial \varepsilon_j/\partial y = 0$, $j = 1, \ldots, k$, then the pollution-income relationship has a positive slope and is linear, i.e.

(a) $\frac{\partial f(p,y)}{\partial y} = \Phi \sum_{j=1}^{k} \varepsilon_j s_j > 0$

(b) $\frac{\partial^2 f}{\partial y^2} = \Phi \sum_{j=1}^{k} \frac{\partial s_j}{\partial y} \varepsilon_j = 0$

Proof:

From the consumers budget constraint we have that:

$\sum_{k=1}^{k} s_j \varepsilon_j = 1$. Since $\Phi > 0$ (a) is true.

Differentiating $\sum_j s_j \varepsilon_j = 1$ with respect to y, and putting $\partial \varepsilon/\partial y = 0$, we get

$\sum_{j=1}^{k} \frac{\partial s_j}{\partial y} \varepsilon_j = 0$, which proves (b)

If $(\partial g/\partial x_i)/(1/p_i) \neq (\partial g/\partial x_j)/(1/p_j)$ for any $i, j = 1, \ldots, k,$ and/or $\partial \varepsilon_j/\partial y \neq 0$, for any $j = 1, \ldots, k$, then the pollution-income relationship can have a positive or negative slope, and be concave or convex even if the pollution function, g, is linear ($\partial^2 g/\partial x_i^2 = 0$, $i = 1, \ldots, k$). Thus, we can conclude that the sufficient conditions for a linear and positive pollution-income relationship are very restrictive and are probably never fulfilled in practice. We can also conclude that the curvature of the pollution-income relationship can take any form, depending not only on preferences, but also on the g-function.

3. Modelling framework

In order to empirically assess the curvature of the household pollution-income relationship we can either estimate a reduced form relation, denoted f in equation (1) for each pollutant, or estimate a structural model for consumer demand and link this to an "emission module", denoted g in equation (1). In any case, however, we need data on emissions, but in the structural case we also need data on consumption and a pollution function for each good. Here we have chosen the second approach for several reasons. One is that we are not only interested in the relation *per se*, but also in the driving forces behind the relation, i.e. whether a specific pattern is mostly driven by g, or by preferences. Another reason is that a structural approach enables us to trace changes in emissions due to an income change back to changes in the consumption basket. If we use a reduced form approach, neither of these objectives can be met. However, as pointed out, the structural approach is demanding in the sense that we need data on how an individual household allocates its budget, and on what the emissions will be under different allocations.

The data we have in this case comes from the Swedish Family Expenditure Survey (FES) 1984, 1988, and 1996. In the FES, households are asked to record their expenditures on non-durables such as food, clothing and public transportation during a four-week period. For some commodities such as petrol and heating the households report their annual expenditure. Apart from real consumption and income, the data include various household characteristics, such as age, family size, and residential location.

Since the data on consumption includes only expenditure on non-durable goods, we implicitly assume that each household's utility function is weakly separable in durables and non-durables, which means that the consumption decision can be modelled as a two-stage budgeting process. In the first stage, disposable income is allocated between durables and non-durables. In the second stage, the household decides the allocation within the non-durable group, given the total allocation to this group. Here we will only model the second stage. A shortcoming of this approach is of course that changes in income will also affect consumption of durables, and hence emissions. Thus the results here may be viewed as short-term results.

Next we have to consider an appropriate framework for the demand model at the microeconomic level. It is clear from the discussion above that our framework should be as flexible as possible in order to encompass a wide range of preferences, while at the same time obeying the constrains originating from the budget constraint and utility maximization. One possible candidate is the Almost Ideal Demand System (Deaton & Muellbauer, 1980) which has a flexible functional form. However, the AIDS model is linear in expenditure, which is a very restrictive assumption. In fact it is very common in microdata that demand patterns vary considerably across households with different levels of income, even when controlled for variations in household characteristics. Banks et al. (1997), for example, found that expenditure on some goods is non-linear in total expenditure (or income) while expenditure on others is linear. Similar results were found by Ghalwash (2006). In the previous section, we showed that the shape of the pollution-income relation depends on derivative of the income elasticity with respect to income, which stresses the importance of including non-linear effects in our demand model. To handle non-linear expenditure effects we employ a quadratic extension of the AIDS model, the so called QUAIDS model (Banks et. al. 1997).[3] Then, given the QUAIDS specification we can write the system of demand equations, in budget share form, as:

$$s_{ijt} = \boldsymbol{\alpha}'_{jt}\mathbf{d}_{it} + \sum_{m=1}^{k}\gamma_{jm}\ln p_{jt} + \boldsymbol{\beta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t] + \boldsymbol{\delta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t]^2 + \upsilon_{ijt}, \quad j = 1,\ldots,k, \qquad (6)$$

where $s_{ijt} = p_{jt}x_{ijt}/y_{it}$ is the budget share for good *j* in household *i* and period *t*, p_{jt} is the price of good *j*, and y_{it} is household *i*'s total expenditure on the goods $m = 1,\ldots,k$. Household *i*'s characteristics are represented by the column vector $\mathbf{d}_{it}$, and the corresponding parameter vectors are denoted $\boldsymbol{\alpha}_{jt}$, $\boldsymbol{\beta}_{jt}$, and $\boldsymbol{\delta}_{jt}$.[4] The last term, υ_{ijt}, is an error term reflecting unobserved (for the researcher) variation in taste.

[3] The specification used here deviates from Banks et al. in the sense that we use the same price index as deflator in the linear and non-linear terms.

[4] It is, of course, straightforward to also include household specific effects on the part containing the price.

Worth noting in equation (6) is that the price of the goods are equal across households in any given time period *t*. This means that, since we will estimate the cross-sections separately, the price will be a constant in the regressions, and hence can be included directly into the intercept term $\boldsymbol{\alpha}$. The system of demand equations to be estimated then becomes a system of Engel curves, i.e.

$$s_{ijt} = \tilde{\boldsymbol{\alpha}}'_{jt}\mathbf{d}_{it} + \boldsymbol{\beta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t] + \boldsymbol{\delta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t]^2 + \upsilon_{ijt},\ j = 1, \ldots k \qquad (7)$$

Differentiating equation (7) with respect to ln*y*, we get

$$\frac{\partial s_{ijt}}{\partial \ln y_{it}} = \boldsymbol{\beta}'_{jt}\mathbf{d}_{it} + 2\boldsymbol{\delta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t],$$

which enables us to write the income, or expenditure, elasticity as:

$$\varepsilon_{ijt} = \frac{1}{s_{ijt}}\left[\boldsymbol{\beta}'_{jt}\mathbf{d}_{it} + 2\boldsymbol{\delta}'_{jt}\mathbf{d}_{it}\ln[y_{it}/P_t]\right] + 1, \qquad j = 1, \ldots, k \qquad (8)$$

The non-linear income effect on the budget share in equation (7) then implies that the income elasticity is a linear function of income. Furthermore we see that the income elasticity and its relation to income can vary between different types of households.

Given estimates of the parameters in our demand model, we can estimate the effect of a change in income on demand for the various goods. Then, given a pollution function related to each good, this in turn enables us to calculate total change in emissions. Here we will focus on three different emissions; carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Furthermore, we assume that emissions of each substance are a linear function of consumption. Emissions from each good are then defined as:[5]

$$E_{jm} = \theta_{jm} \cdot x_j \qquad (9)$$

where x_j is the real consumption of good *j*, and θ_{jm} is the emission of substance *m* per unit of real consumption of good *j,*[6] for $m = CO_2, SO_2, NO_x$

[5] The household index and time index have been suppressed to spare us from notational clutter.

[6] The emission coefficient θ_i, measure the direct emissions from the household's consumption of heating and transport. For all other goods, the emission coefficients measure the indirect emissions from the household's consumption, i.e. the indirect emissions include the emissions from the production of the goods that the household consume.

A household’s total emission can then be written as:

$$E_m = \sum_{j=1}^{k} E_{jm} = \sum_{j=1}^{k} \theta_{jm} \cdot x_j \ , \quad m = CO_2, SO_2, NO_x \tag{10}$$

The change in emissions due to a change in income is then:

$$\frac{\partial E_m}{\partial y} = \sum\nolimits_j \frac{\partial x_j}{\partial y} \frac{\partial E_m}{\partial x_j} = \sum\nolimits_i \frac{\partial x_j}{\partial y} \theta_{jm} \ , \qquad m = CO_2, SO_2, NO_x \tag{11}$$

4. Data

To estimate the demand model we use pooled cross-sectional data from the Swedish Family Expenditure Survey (FES) of 1984, 1988 and 1996, comprising in all about 10000 observations. FES is a comprehensive microdata survey on household expenditure, income and characteristics. For the choice of consumption of non-durable goods we aggregate household expenditure into eight goods (food, beverages, heating, petrol, other transportation, recreation, clothes and other non-durable goods), and link emission data to each type of good.

It is very important to achieve data compatibility between the three surveys. There were some differences in the classification of goods and in household characteristics. To overcome these problems we aggregated expenditures in homogeneous goods following survey definitions, and used the same methodology for demographics by defining new variables containing the same household characteristics in the three surveys.

Table 1 summarizes the changes in the expenditure share for each good between 1984 and 1996, along with the 1996 share of three different emissions; carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxides (NO_x). As shown, household expenditure for food, beverages and clothes has been fairly stable over time, although there is a weak negative trend in the food share. However, the share for heating and other transportation both decreased slightly between 1984 and 1988, while approximately 17% of the household expenditure went to heating in 1984, this share had declined to 16% in 1988 and to 9% in 1996. Finally, the table also depicts a simultaneous rise in the budget share of both petrol and recreation between 1988 and 1996.

Table 1: Descriptive statistics of budget and emission shares of eight types of good. Percentage of total expenditures and emissions. Emission intensities are in kg/1000 SEK.

	Budget share			Emission share 1996			Emission intensities		
	1984	1988	1996	CO_2	NOx	SO_2	CO_2	NOx	SO_2
Food	35.0	28.0	31.0	8.4	15.1	10.8	19.80	0.02	0.18
Beverages	4.0	4.0	5.0	0.5	0.6	0.7	7.27	0.01	0.04
Heating	17.0	16.0	9.0	29.1	9.2	50.9	178.56	0.23	0.28
Petrol	6.0	5.0	8.0	44.7	51.3	13.2	292.34	0.06	1.48
Other transp.	6.0	5.0	3.0	4.3	8.2	2.5	118.16	0.05	1.09
Recreation	3.0	4.0	10.0	2.4	4.3	4.5	13.90	0.02	0.13
Clothes	9.0	9.0	10.0	1.0	1.2	1.5	6.71	0.01	0.04
Others	20.0	29.0	24.0	9.6	10.1	15.9	8.67	0.01	0.05
Sum	100.0	100.0	100.0	100.0	100.0	100.0			

Note: The emissions from transport and heating are direct, whereas the emissions from all other goods are indirect

Concerning the budget shares and emission shares in the 1996 survey, Table 1 shows that petrol, with an expenditure share of 8%, is the good with the largest contribution of both CO_2 emissions (45%) and NO_x emissions (51%). Compared to the emissions of CO_2 and NO_x, the SO_2 share for petrol is much smaller (only 13%). One reason for the relatively low emissions of sulfur dioxide from petrol is the SO_2 tax on petrol, which has led to a move from petrol with high to low sulfur content. In fact, the table reveals that heating has the largest share of sulfur dioxide emissions, amounting to about 51%.

From Table 1 we also see that food consumption, with 31% of total expenditure, generates relatively large emissions of sulfur dioxide and NO_x. In relation to its share of expenditure, recreation also constitutes a relatively large share of the emissions of sulfur dioxide and NO_x.

Household characteristics may affect consumer behavior with respect to these eight goods, and hence also emissions. There are basically two different ways to consider different household characteristics in the model estimation (Pollak and Wales, 1992). The first technique is to consider the sample as a whole and use different dummy variables to capture different household characteristics. The second is to divide the sample into homogenous sub-samples depending on household characteristics. In this paper, we follow the first approach. The variables relating to household characteristics include three dummy variables for the cases when the household has one child, two children, or more than two children less than 18 years of age, and five regional dummy variables for the six census regions in the surveys[7]. In

[7] To avoid perfect collinearity we dropped a variable from each set of dummy variables.

the estimation, we use total expenditure rather than income because expenditure better reflects permanent income.

5. Estimation results

In this section we present some of the estimation results from the demand model. Concerning estimation we have, in principle, two approaches to follow. The first is to estimate each equation separately using ordinary least squares. The second is to estimate the equations as a system using seemingly unrelated regressions. We have chosen the latter, mainly motivated by the belief that errors between equations are correlated, hence gaining some efficiency.

We start the analysis by testing the functional form for the expenditure system in order to decide whether the non-linear expenditure term should enter the model or not. Table 2 shows the results of this test.

Table 2: Likelihood-ratio tests for non-linearity.

	1984	1988	1996
Non-Linearity	110*	190*	141*

* Non-linearity cannot be rejected at the 5% level.

The results in Table 2 indicate that we can reject linearity for the whole expenditure system. According to the test results and specification in equation (7), the demand system for the eight goods is estimated by using the SURE technique (Seemingly Unrelated Regression Equations). Tables A1-A3 in the appendix provide estimates of the parameters of the model. Given the parameter estimates, income elasticities can be calculated according to equation (8). Table 3 presents the resulting income elasticities, together with their standard errors. The elasticities in Table 3 are evaluated at the mean budget shares and the mean total expenditure for all household in each survey. The standard errors are computed with the delta method (see Greene, 2000).

Table 3. Estimated income elasticities.

	1984		1988		1996	
	Budget elasticity	(Standard error)	Budget elasticity	(Standard error)	Budget elasticity	(Standard error)
Food	0.79	(0.01)	0.70	(0.01)	0.66	(0.02)
Beverages	0.90	(0.04)	0.63	(0.05)	0.84	(0.07)
Heating	0.59	(0.03)	0.27	(0.03)	0.71	(0.05)
Petrol	0.77	(0.02)	0.68	(0.03)	0.67	(0.05)
Other transport	1.34	(0.04)	1.25	(0.05)	1.77	(0.25)
Recreation	1.49	(0.05)	1.65	(0.04)	1.91	(0.08)
Clothes	1.56	(0.03)	1.34	(0.03)	1.34	(0.06)
Other goods	1.27	(0.01)	1.42	(0.006)	1.02	(0.02)

Note: Standard errors within parentheses.

Table 3 reveals that all goods were normal goods over the various cross-sections, since they had non-negative income elasticity. Further it shows that food, beverages, heating and petrol seems to be necessities, i.e. they have income elasticities lower than one, whereas other transport, recreation, clothes and other goods appear to be luxuries, since they have income elasticities that are higher than one.[8]

Table 3 also reveals relatively low income elasticity for heating in 1984 and 1988, and for food in 1996, whereas recreation seems to have become monotonically more income-elastic over time.

Regarding the change in income elasticity over time, we can conclude that the income elasticities for food and petrol were decreasing between 1984 and 1996. On the other hand, those for heating, beverages, other transport and other goods were decreasing between 1984 and 1988, but increasing between 1988 and 1996, whereas the income elasticity for recreation was increasing monotonically between 1984 and 1996.

Pollution – Income Relationship

To analyze the EKC hypothesis at the household level we must empirically derive the pollution-income relationship stated in equation (1) using the parameter estimates in Tables A1-A3 and the emission data. Given an empirical version of equation (1), it is straightforward to calculate the slope and curvature of the relationship. However, applying Proposition 1 reveals directly that the slope of the pollution-income relationship is positive for an average

[8] These results support the results of Ghalwash (2006).

household. According to the results in Table 3, all goods are normal goods, i.e. the average income elasticity is positive for all goods, which is a sufficient condition for a positive slope according to Proposition 1. Thus we can conclude that a (small) rise in household income will give rise to an increase in the household's emission of sulfur, nitrogen oxides, and carbon dioxide. Here it should be pointed out that this is valid under the assumptions that the technology is "fixed", i.e. the emission intensities do not change, and that the prices remain unchanged. These may be plausible assumptions for marginal changes, but they are more questionable for large changes in income.

The second issue is related to the curvature of the pollution-income relation. Since the sufficient condition for a linear relationship stated in Proposition 1 is not fulfilled, the results in Table 3 cannot be used directly to reveal the curvature. However, by using the estimation results in table A3 in the appendix in equation (6), we can calculate the curvature at an arbitrary point. Table 4 presents the result of this calculation at the mean for the budget shares and the mean income. For all three pollutants the results suggest that the relation between pollution and income is non-linear and concave. Based on this we can conclude that pollution is increasing with income, but at a decreasing rate, for all three pollutants. This result is valid at least in the neighborhood of the point of evaluation (at the mean of the data). Concerning the issue of an EKC, the results here do not rule out the possibility of an EKC at the household level.

Table 4. Curvature of income-pollution relations, evaluated at the mean.

Pollutant	Curvature, $\partial^2 f/\partial y^2$
CO_2	-7.46
SO_2	-0.003
NO_x	-0.025

One implication of the results in Table 4 is that the aggregate pollution-income relationship will depend on income distribution. Due to the concave relationship, according to Table 4, a redistribution of income from high-income households to low-income households, *ceteris paribus*, will increase emissions of all three pollutants. Thus, the results here do to some extent support the findings of Heerink et al. (2001) and Huang (2005).

Figure 2 presents the pollution-income relationship for an average Swedish household, in order to illustrate the pollution-income relationship for non-marginal changes in income. It shows that the relationship is monotonically positive within the range of the actual income distribution. Moreover it can be seen that the concavity is more pronounced for CO_2 and SO_2, compared to NOx. Figure 2 also illustrates that mean pollution over all households, $(\overline{E})$, is lower than pollution evaluated at the mean income $E(\overline{y})$. This implies, as stated above, that an increase in income equality will increase aggregate emissions of all three pollutants.

The concavity property of the pollution-income relationship follows from the magnitudes of the income elasticities reported in Table 3, in combination with the emission intensities reported in Table 2. From Table 3 we have that the income elasticities for the most emission intensive goods are lower than one, whereas less-emission intensive goods, such as recreation, have income elasticities higher than one. Thus, an increase in income will lead to a more than proportional increase in consumption of the low-intensity goods, and less than proportional increase in the high-intensity good. Taken together this implies that emissions are increasing, but at a decreasing rate. However, due to the restrictions we have imposed, the simulations in Figure 2 should be viewed as illustrations rather than predictions. Perhaps the most serious restriction is that the emission intensities are fixed and independent of income. A more realistic setting is that income growth, due to for example technological progress, also affects the emission intensities, and hence also shifts the curve downwards and changes the curvature. If we interpret the income growth in Figure 2 as a result of technological progress, the resulting pollution-income relation may perhaps be viewed as a "worst case" concerning environmental effects. Another reason as to why a fixed intensity is restrictive is that an income change may give rise to substitution *within* our commodity groups, and hence induce a change in emission intensities. Thus, a fixed emission intensity is valid only if there is no substitution within the groups, or if the emission intensities are similar for all the goods within the commodity group.

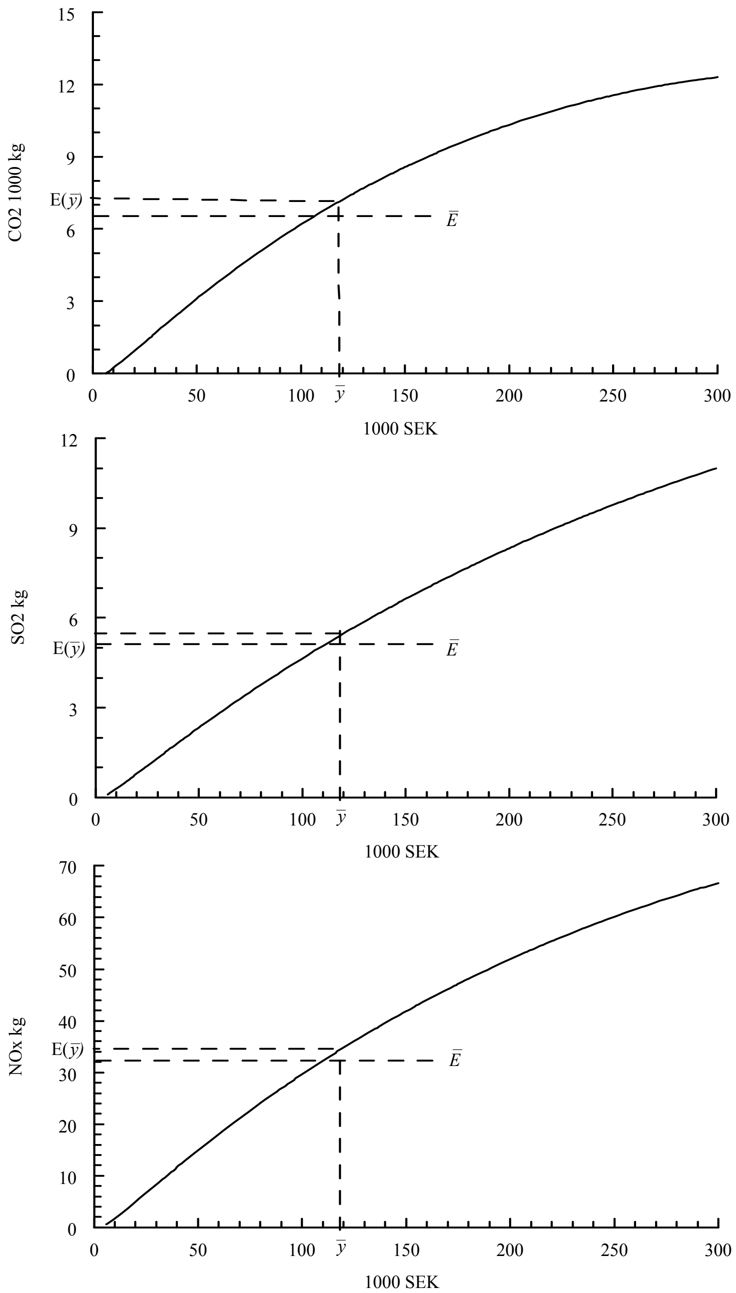

Figure 2. The pollution-income relationship for an average Swedish household.

Figure 3 presents the household income-pollution relationships in different regions. The relationship is evaluated for an average household in four of the regions. Here we see a clear pattern in the sense that the relationships are less concave for a typical household in Stockholm than in the rest of the country.[9] Furthermore, as can be seen in Figure 3, it is more

[9] An exception though is NOx, for which the relationship is almost linear for the northern rural area.

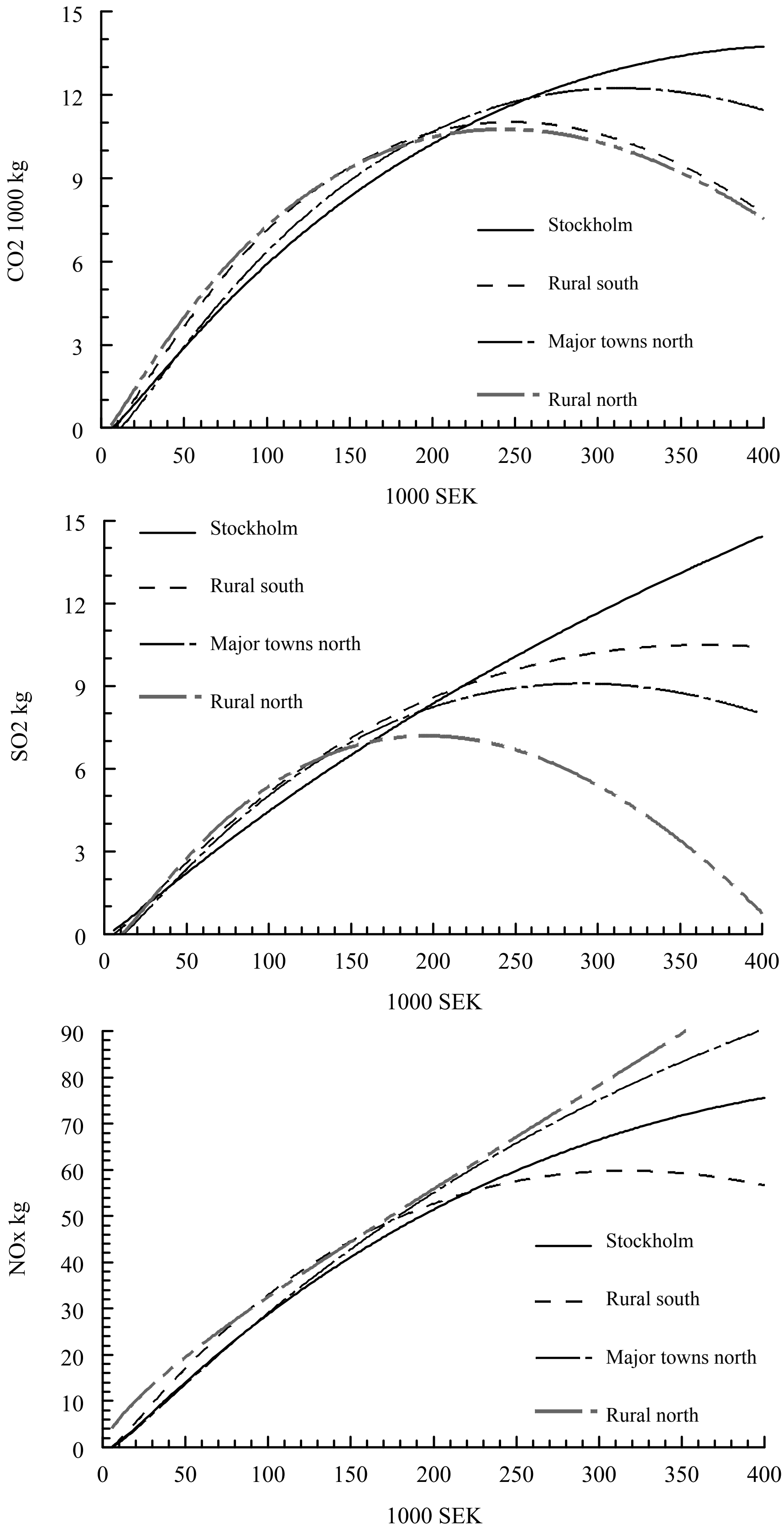

Figure 3. The pollution-income relationship for an average household in Stockholm, the rural south, in northern major towns, and in the rural north.

likely that an EKC type of relationship will exist in northern towns and rural areas for CO_2 and SO_2 compared with NO_x since the pollution curve bends down as income becomes sufficiently high. One implication of this pattern is that what matters is not only income distribution in the usual sense, but also the regional distribution of growth. Thus, if we wish to test the EKC hypothesis on the aggregate level we have to consider both of these factors.

Income distribution and aggregate pollution

One conclusion from the above discussion is that the individual, or household, pollution-income relationship is non-linear, which in turn implies that the aggregate relationship depends not only on aggregate income but also on how income is distributed. To illustrate this we will investigate how a change in the income distribution we observe in our data would affect aggregate emissions, or emissions per capita. To do this we assume that income distribution follows a lognormal distribution, i.e. $\ln y \sim N(m, s)$, where m is the mean and s the standard deviation. Given this distribution we can write the mean (μ) and standard deviation (σ) for y, in terms of m and s as:

$$\mu = e^{\frac{2m+s^2}{2}}, \ \sigma = \sqrt{e^{2m+2s^2} - e^{2m+s^2}}$$

Given our data we can estimate m and s as the mean and standard deviation of $\ln y$. Figure 4 displays the empirical distribution for y in 1996 showing that this empirical distribution has a shape typical of a lognormal distribution. We see also that the distribution in Figure 4 corresponds to a Gini coefficient of 0.33.[10]

[10] The Gini coefficient is a measure of inequality, and takes a value between 0 and 1, where 0 corresponds to perfect equality (everyone has the same income) and 1 to perfect inequality (where one person has all the income, and everyone else has zero income). The Gini value obtained here differs to some extent from other estimates of the Gini coefficient. The reason is that the Gini coefficient in this case correpsponds to the distribution of consumption expenditures on non-durable goods for this particular sample. According to the United Nations WIDER database (http://www.wider.unu.edu/wiid/wiid.htm) the Gini coefficient for Sweden was 0.27 in 1996, which should be compared to 0.39 for the USA. Given a lognormal distribution the Gini coefficient can be calculated as $G = 2\Phi(s/\sqrt{2}) - 1$, where Φ is the standard cumulative normal distribution (McDonald, 1984)

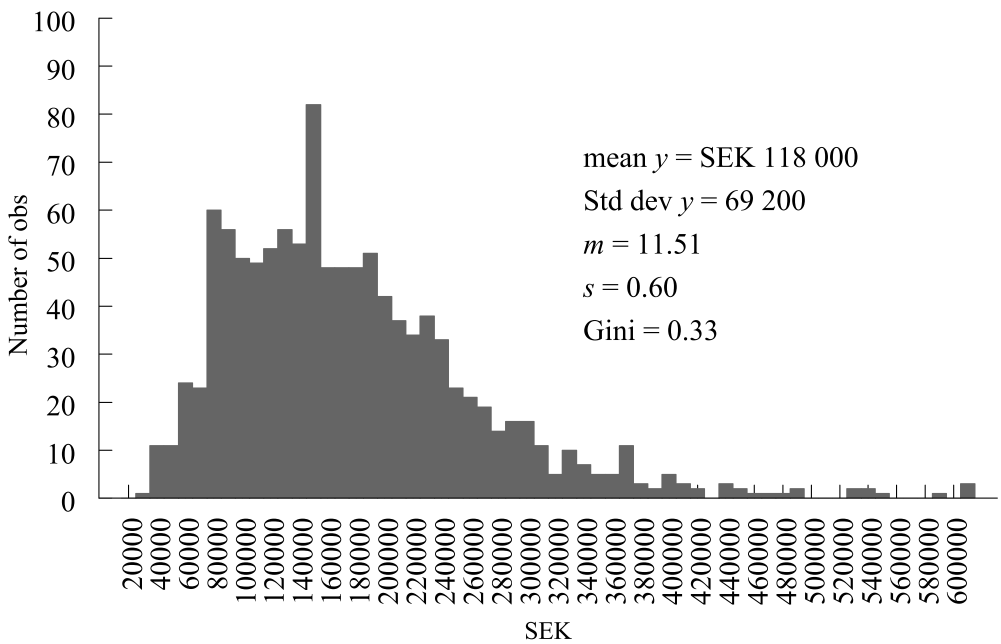

Figure 4. Distribution of expenditures on non-durable goods in the 1996 household survey.

To illustrate the effect on aggregate emissions from a change in income distribution we change the value of *s* in the lognormal income distribution. However, in order to keep average income unchanged we adjust the value of *m*.[11]

Table 5 displays the results from three simulations. The scenario with superscript 0 refers to the outcome at the observed *s*, whereas 1 is a low variance scenario ($s^1 = 0.5 \cdot s^0$), and 2 is a high variance scenario ($s^2 = 1.5 \cdot s^0$). In each scenario we sample 30 000 observations from the scenario-specific income distribution and calculate the emissions of each substance according to equation (10). We repeat this 20 times and calculate the average emissions.

Table 5. Income distribution and effects on aggregate emissions. Simulations assuming a lognormal income distribution.

	Low variance	Reference	High variance
S	0.30	0.60	0.90
σ	52 716	78 087	100 304
$\bar{y}$	119 000	119 000	119 000
Gini	0.23 (-30%)	0.33	0.39 (+18%)
CO_2 (1000 kg/cap)	6.93 (+6.3%)	6.52	6.01 (-7.8%)

[11] Since $\bar{y} = e^{m+s^2/2}$, we have that $d\bar{y} = e^{m+s^2/2}dm + 0.5e^{m+s^2/2}ds^2 = 0$, which gives us that $dm = -0.5ds^2$

SO_2 (kg/cap)	5.35 (+4.5%)	5.12	4.88 (-4.7%)
NO_x (kg/cap)	33.70 (+4%)	32.40	30.96 (-4.4%)

From Table 5 we see that, as expected, a higher degree of inequality will lead to a decrease in total emissions, and vice versa. We also see that the emission effect is most pronounced for CO_2. These results raise several interesting questions related to the Environmental Kuznets issue including to what extent income equalization during a growth path counteracts a possible reduction in emission growth among the rich part of a population.

6. Concluding remarks

The analysis in this paper is motivated by the recent literature emphasizing the importance of income distribution for the aggregate relation between pollution and income. The main finding from previous studies is that if the micro, or individual pollution-income relationship is non-linear, then the aggregate pollution, for say a whole country, will depend not only on average, or aggregate income, but also on how income is distributed. Our aim was not only to determine which conditions on individual preferences and the link between consumption and pollution would lead to a linear relationship, but also to empirically assess the relationship.

We have shown that the sufficient condition for a positive and linear pollution-income relationship is a rather restrictive combination of certain preferences and a very specific link between consumption and pollution. In fact, it is not very likely that we would observe such a combination in practice. Thus we can conclude that is not possible to say much about the curvature *a priori* rather, it is an empirical issue that depends on the particular links between consumption and pollution, as well as preferences over the various consumption goods.

The results from the empirical analysis show that, at least in a close neighborhood of observed income and pollution, we can reject linearity for all three types of pollutions, CO_2, SO_2, and NO_x. According to our results the pollution-income relationships are all strictly concave. Thus the implication is that income distribution seems to matter in the sense that equalization of income will lead to higher emissions. Furthermore it has been shown that the slope as well as the curvature differ between different types of households, which means that preferences differ across households. A consequence of this is that regional distribution will also have implications for aggregate pollution under a growth scenario. The basic reason for the concavity property can be found in the negative correlation between emission intensities and income elasticities for the various goods. Goods with relative high income elasticities tend to have relatively low emission intensities, and vice versa. This means that an increase in income tends to give rise to a move from high emission-intensive goods to low emission-intensive goods. A typical example is consumption of petrol for cars and consumption of recreation. Petrol has a relatively low income elasticity (below one), but very high emission intensity, whereas recreation has a relatively high income elasticity, but relatively low emission intensity. Hence, consumption of petrol will grow at a lower rate than income, and recreation at a higher rate, which gives rise to a slowdown in emissions since recreation is less emission-intensive.

The analysis we provide here is admittedly based on several restrictive assumptions, and the results should for this reason be handled with care. Perhaps the most restrictive assumption is the fixed emission intensities, at least if the objective is to analyze the effects of large changes in income. An interesting prospect for future research is thus to have a more general equilibrium type of approach in which the emission intensities are functions of income, since income to some extent is related to technical progress which in turn also affects production and abatement technology. For such an approach to be possible we would need time-series data for the emission intensities; work to compile a database with time series is currently underway.

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Appendix 1

Table A1: Parameter estimates from the demand model in 1984, t-ratio within parentheses.

	Food	Beverages	Heating	Petrol	Other transport	Recreation	Clothes
Intercept of the expenditure equation							
Constant	-3.44	0.33	5.26	-1.66	0.29	0.79	1.03
	(-4.77)	(0.86)	(5.65)	(-4.60)	(0.57)	(1.92)	(1.80)
R1	-0.45	-1.26	-1.14	-0.07	0.03	-0.48	0.16
	(-0.60)	(-2.51)	(-1.08)	(-.13)	(0.04)	(-0.91)	(0.27)
R2	-1.83	-1.22	0.03	0.03	-0.35	0.42	1.79
	(-1.71)	(-1.81)	(0.02)	(0.04)	(-0.30)	(0.59)	(2.24)
R3	-1.14	-0.06	-2.70	-0.48	0.42	0.22	-1.18
	(-1.28)	(-0.09)	(-2.05)	(-0.91)	(0.59)	(0.23)	(-1.62)
R4	-1.42	-0.54	0.50	0.16	1.79	-1.18	-0.44
	(-1.25)	(-0.80)	(0.32)	(0.27)	(2.24)	(-1.62)	(-0.34)
R5	-8.99	-2.86	1.43	-5.20	0.76	0.53	8.83
	(-2.63)	(-1.98)	(0.36)	(-3.72)	(0.33)	(0.34)	(3.37)
Ch1	3.01	0.05	-0.50	-0.45	-1.83	-1.14	-1.42
	(1.40)	(0.06)	(-0.23)	(-0.60)	(-1.71)	(-1.28)	(-1.25)
Ch2	0.05	0.51	-2.35	-1.26	-1.22	-0.06	-0.54
	(0.06)	(0.49)	(-.68)	(-2.51)	(-1.81)	(-0.09)	(-0.80)
Ch3	-0.50	-2.35	4.03	-1.14	0.03	-2.70	0.50
	(-0.23)	(-.68)	(0.96)	(-1.08)	(0.02	(-2.05)	(0.32)
Linear expenditure coefficients							
Constant	0.72	-0.05	-0.82	0.43	-0.07	-0.15	-0.22
	(5.74)	(-0.71)	(-5.07)	(7.77)	(-0.73)	(-2.08)	(-2.23)
R1	0.08	0.22	0.22	0.02	-0.0004	0.08	-0.03
	(0.67)	(2.59)	(1.18)	(0.16)	(-0.004)	(0.91)	(-0.26)
R2	0.31	0.22	0.02	-0.0004	0.05	-0.08	-0.35
	(1.66)	(1.85)	(0.09)	(-0.004)	(0.27)	(-0.61)	(-2.28)
R3	0.20	0.01	0.47	0.08	-0.08	-0.04	0.21
	(1.28	(0.10	(2.09)	(0.91)	(-0.61)	(-0.22)	(1.61)
R4	0.25	0.10	-0.07	-0.03	-0.35	0.21	0.08
	(1.29)	(0.85)	(-0.28)	(-0.26)	(-2.28)	(1.61)	(0.35)
R5	1.57	0.49	-0.27	0.91	-0.33	-0.11	-1.50
	(2.61)	(1.96)	(-0.39)	83.66)	(-2.22)	(-0.39)	(-3.26)
Ch1	-0.53	-0.01	0.12	0.08	0.31	0.20	0.25
	(-1.41)	(-0.07)	(0.31)	(0.67)	(1.66)	(1.28	(1.29)
Ch2	-0.01	-0.09	0.39	0.22	0.22	0.01	0.10
	(-0.07)	(-0.54)	(1.62)	(2.59)	(1.85)	(0.10	(0.85)
Ch3	0.12	0.39	-0.79	0.22	0.02	0.47	-0.07
	(0.31)	(1.62)	(-1.09)	(1.18)	(0.09)	(2.09)	(-0.28)
Quadratic expenditure coefficients							
Constant	-0.03	0.001	0.03	-0.01	0.004	0.007	0.01
	(-6.21)	(0.65)	(4.66)	(-4.87)	(1.07)	(2.33)	(2.81)
R1	-0.004	-0.01	-0.01	-0.001	-0.0001	-0.003	0.001
	(-0.73)	(-2.66)	(-1.28)	(-0.18)	(-0.03)	(-0.90)	(0.28)
R2	-0.01	-0.009	-0.002	-0.0001	-0.002	0.003	0.02
	(-1.61	(-1.89)	(-0.20)	(-0.03)	(-0.20)	(0.62)	(2.31)
R3	-0.008	-0.0004	-0.02	-0.003	0.003	0.002	-0.009
	(-1.29)	(-0.09)	(-2.13)	(-0.90)	(0.62)	(0.22)	(-1.61)
R4	-0.01	-0.004	0.003	0.001	0.02	-0.009	-0.004
	(-1.34)	(-0.90)	(0.25)	(0.28)	(2.31)	(-1.61)	(-0.37)
R5	-0.06	-0.02	0.01	-0.04	0.003	0.005	0.06
	(-2.58)	(-1.94)	(0.41)	(-3.61)	(0.21)	(0.45)	(3.14)
Ch1	0.02	0.001	-0.006	-0.004	-0.01	-0.008	-0.01
	(1.43)	(0.11)	(-0.37)	(-0.73)	(-1.61	(-1.29)	(-1.34)
Ch2	0.001	0.004	-0.02	-0.01	-0.009	-0.0004	-0.004
	(0.11)	(0.57)	(-1.56)	(-2.66)	(-1.89)	(-0.09)	(-0.90)
Ch3	-0.006	-0.02	0.34	-0.01	-0.002	-0.02	0.003
	(-0.37)	(-1.56)	(1.21)	(-1.28)	(-0.20)	(-2.13)	(0.25)

Notes: Ch1= 1 child below 18, Ch2= 2 children below 18, Ch3= more than 2 children below 18, R1 = Stockholm, R2=Gothenburg/Malmö, R3= major towns, R4=southern areas, R5= major towns northern areas.

Table A2: Parameter estimates from the demand model in 1988, t-ratio within parentheses.

	Food	Beverages	Heating	Petrol	Other transport	Recreation	Clothes
			Intercept of the expenditure equation				
Constant	-4.55	0.98	6.00	0.37	0.51	0.61	-0.71
	(-6.02)	(2.12)	(7.28)	(0.93)	(0.89)	(1.85)	(-1.20)
R1	-0.78	-0.27	0.69	-1.24	-1.08	0.68	-1.45
	(-1.01)	(0.50)	(0.76)	(-2.18)	(-1.87)	(1.60)	(-2.37)
R2	-1.66	-0.99	-1.17	-1.08	-1.63	-0.99	0.75
	(-1.45)	(-1.42)	(-0.95)	(-1.87)	(-1.44)	(-1.84)	(0.85)
R3	2.76	-1.15	-2.58	0.68	-0.99	-0.95	-0.95
	(3.83)	(-2.19)	(-3.05)	(1.60)	(-1.84)	(-1.81)	(-1.81)
R4	-0.55	-1.11	-1.31	-1.45	0.75	0.69	-0.72
	(-0.55)	(-1.52)	(-1.00)	(-2.37)	(0.85)	(1.23)	(-0.56)
R5	3.95	-1.87	-11.31	-2.52	7.52	-0.69	-0.47
	(1.93)	(-2.00)	(-5.53)	(-3.09)	(5.35)	(-0.93)	(-0.32)
Ch1	2.53	-0.98	3.27	-0.78	-1.66	2.76	-0.55
	(1.00)	(-0.95)	(1.63)	(-1.01)	(-1.45)	(3.83)	(-0.55)
Ch2	-0.98	0.15	-0.85	-0.27	-0.99	-1.15	-1.11
	(-0.95)	(0.12)	(-0.66)	(0.50)	(-1.42)	(-2.19)	(-1.52)
Ch3	3.27	-0.85	4.64	0.69	-1.17	-2.58	-1.31
	(1.63)	(-0.66)	(1.42)	(0.76)	(-0.95)	(-3.05)	(-1.00)
			Linear expenditure coefficients				
Constant	0.89	-0.14	-0.88	-0.05	-0.08	-0.12	0.09
	(6.91)	(-1.83)	(-6.31)	(-0.71)	(-1.02)	(-1.82)	(0.97)
R1	0.13	0.05	-0.11	0.22	0.18	-0.11	0.25
	(0.95)	(0.54)	(-0.76)	(2.25)	(1.98)	(-1.46)	(2.42)
R2	0.26	0.17	0.21	0.18	0.28	0.18	-0.12
	(1.37)	(1.43)	(1.00)	(1.98)	(1.74)	(1.99)	(-0.79)
R3	-0.48	0.19	0.14	-0.11	0.18	0.17	-0.11
	(-3.92)	(2.09)	(2.98)	(-1.46)	(1.99)	(1.94)	(-1.17)
R4	0.08	0.19	0.20	0.25	-0.12	-0.11	0.14
	(0.42)	(1.52)	(0.91)	(2.42)	(-0.79)	(-1.17)	(0.61)
R5	-0.65	0.32	1.94	0.43	1.29	0.13	-0.47
	(-1.82)	(1.95)	(5.55)	(3.07)	(-5.28)	(0.98)	(-0.32)
Ch1	-0.41	0.16	-0.51	0.13	0.26	-0.48	0.08
	(-0.95)	(0.96)	(-1.51)	(0.95)	(1.37)	(-3.92)	(0.42)
Ch2	0.16	-0.04	0.13	0.05	0.17	0.19	0.19
	(0.96)	(-0.18)	(0.60)	(0.54)	(1.43)	(2.09)	(1.52)
Ch3	-0.51	0.13	-0.82	-0.11	0.21	0.14	0.20
	(-1.51)	(0.60)	(-1.49)	(-0.76)	(1.00)	(2.98)	(0.91)
			Quadratic expenditure coefficients				
Constant	-0.04	0.005)	0.03	0.002	0.005	0.00	-0.003
	(-7.42)	(1.61)	(5.51)	(0.58)	(1.14)	(2.13)	(-0.60)
R1	-0.005	-0.002	0.005	-0.009	-0.008	0.004	-0.01
	(-0.91)	(-0.57)	(0.75)	(-2.30)	(-1.91)	(1.33)	(-2.45)
R2	-0.01	-0.007	-0.009	-0.008	-0.01	-0.008	0.005
	(-1.29)	(-1.43)	(-1.06)	(-1.91)	(-1.50)	(-2.13)	(0.74)
R3	0.02	-0.008	-0.02	0.004	-0.008	-0.008	0.005
	(4.00)	(-1.99)	(-2.90)	(1.33)	(-2.13)	(-2.07)	(1.13)
R4	-0.003	-0.008	-0.007	-0.01	0.005	0.005	-0.006
	(-0.39)	(-1.52)	(-0.82)	(-2.45)	(0.74)	(1.13)	(-0.65)
R5	0.03	-0.01	-0.08	-0.02	0.05	-0.006	0.08
	(1.72)	(-1.90)	-(5.39)	(-3.03)	(5.20)	(-1.03)	(0.33)
Ch1	0.02	-0.007	0.02	-0.005	-0.01	0.02	-0.003
	(0.90)	(-0.96)	(1.41)	(-0.91)	(-1.29)	(4.00)	(-0.39)
Ch2	-0.007	0.002	-0.005	-0.002	-0.007	-0.008	-0.008
	(-0.96)	(0.24)	(-0.55)	(-0.57)	(-1.43)	(-1.99)	(-1.52)
Ch3	0.02	-0.005	0.04	0.005	-0.009	-0.02	-0.007
	(1.41)	(-0.55)	(1.57)	(0.75)	(-1.06)	(-2.90)	(-0.82)

Notes: Ch1= 1 child below 18, Ch2= 2 children below 18, Ch3= more than 2 children below 18. R1 = Stockholm, R2=Gothenburg/Malmö, R3= major towns, R4=southern areas, R5= major towns northern areas.

Table A3: Parameter estimates from the demand model in 1996, t-ratio within parentheses.

	Food	Beverages	Heating	Petrol	Other transport	Recreation	Clothes
	Intercept of the expenditure equation						
Constant	-0.69	1.84	-0.74	-3.23	1.48	3.72	-0.15
	(-0.66)	(2.38)	(-0.55)	(-4.53)	(2.96)	(3.30)	(-0.15)
R1	-1.13	-1.07	1.84	3.24	-0.35	-1.41	0.14
	(-0.92)	(-1.30)	(1.64)	(2.74)	(-0.55)	(-1.12)	(0.11)
R2	-2.35	-2.50	-2.18	-0.35	1.44	0.25	1.20
	(-2.73)	(-3.64)	(-2.22)	(-0.55)	(2.14)	(0.30)	(1.09)
R3	2.57	-1.48	-2.95	-1.41	0.25	2.32	0.04
	(1.33)	(-1.316)	(-1.99)	(-1.12)	(0.30)	(0.86)	(0.02)
R4	2.44	-1.32	-5.72	0.14	1.20	0.04	-0.90
	(1.27)	(-0.85)	(-2.61)	(0.11)	(1.09)	(0.02)	(-0.26)
R5	0.04	-4.71	-9.42	0.61	9.46	-1.66	7.84
	(0.005)	(-1.23)	(1.94)	(0.11)	(3.23)	(-0.18)	(1.22)
Ch1	0.24	0.22	-2.58	-1.13	-2.35	2.57	2.44
	(0.09)	(0.18)	(-1.65)	(-0.92)	(-2.73)	(1.33)	(1.27)
Ch2	0.22	-0.38	-1.25	-1.07	-2.50	-1.48	-1.32
	(0.18)	(-0.24)	(-0.73)	(-1.30)	(-3.64)	(-1.316)	(-0.85)
Ch3	-2.58	-1.25	1.91	1.84	-2.18	-2.95	-5.72
	(-1.65)	(-0.73)	(0.38)	(1.64)	(-2.22)	(-1.99)	(-2.61)
	Linear expenditure coefficients						
Constant	0.26	-0.24	0.11	0.59	-0.26	-0.73	0.009
	(1.40)	(-2.19)	(0.72)	(4.73)	(-3.02)	(-3.69)	(0.05)
R1	0.19	0.17	-0.33	-0.57	0.06	0.27	-0.03
	(0.92)	(1.23)	(-1.71)	(-2.72)	(0.58)	(1.42)	(-0.13)
R2	0.41	0.43	0.39	0.06	-0.24	-0.04	-0.23
	(2.87)	(3.61)	(2.34)	(0.58)	(-2.05)	(-0.29)	(-1.17)
R3	-0.46	0.25	0.53	0.27	-0.04	-0.40	-0.003
	(-1.36)	(1.28)	(2.06)	(1.42)	(-0.29)	(-0.85)	(-0.01)
R4	-0.40	0.25	1.06	-0.03	-0.23	-0.003	0.17
	(-1.21)	(0.94)	(2.67)	(-0.13)	(-1.17)	(-0.01)	(0.28)
R5	-0.005	0.18	1.68	-0.08	-1.63	0.37	-1.43
	(0-003)	(2.10)	(1.98)	(-0.09)	(-3.19)	(0.22)	(-1.28)
Ch1	0.006	-0.03	0.44	0.19	0.41	-0.46	-0.40
	(0.12)	(-0.14)	(1.62)	(0.92)	(2.87)	(-1.36)	(-1.21)
Ch2	-0.03	0.06	0.21	0.17	0.43	0.25	0.25
	(-0.14)	(0.23)	(0.73)	(1.23)	(3.61)	(1.28)	(0.94)
Ch3	0.44	0.21	-0.32	-0.33	0.39	0.53	1.06
	(1.62)	(0.73)	(-0.38)	(-1.71)	(2.34)	(2.06)	(2.67)
	Quadratic expenditure coefficients						
Constant	-0.01	0.01	-0.005	-0.03	0.01	0.04	0.001
	(-1.83)	(2.10)	(-0.79)	(-4.81)	(3.09)	(4.17)	(0.14)
R1	-0.008	-0.007	0.02	0.02	-0.01	-0.01	0.001
	(-0.93)	(-1.16)	(1.77)	(2.68)	(-1.33)	(-1.33)	(0.16)
R2	-0.02	-0.02	-0.02	-0.003	0.01	0.002	0.01
	(-2.84)	(-3.58)	(-2.44)	(-0.59)	(1.96)	(0.28)	(1.25)
R3	0.02	-0.01	-0.02	-0.01	0.002	0.02	-0.001
	(1.39)	(-1.26)	(-2.10)	(-1.33)	(0.28)	(0.83)	(-0.01)
R4	0.01	-0.01	-0.04	0.001	0.01	-0.001	-0.008
	(1.15)	(-1.03)	(-2.71)	(0.16)	(1.25)	(-0.01)	(-0.30)
R5	0.0002	-0.03	-0.07	0.002	0.07	-0.02	0.06
	(0.003)	(-1.21)	(-2.01)	(0.06)	(3.15)	(-0.28)	(1.33)
Ch1	-0.002	0.001	-0.02	-0.008	0.02	0.02	0.01
	(-0.11)	(0.09)	(-1.59)	(-0.93)	(1.39)	(1.39)	(1.15)
Ch2	0.001	-0.003	-0.008	-0.007	-0.01	-0.01	-0.01
	(0.09)	(-0.21)	(-0.69)	(-1.16)	(-1.26)	(-1.26)	(-1.03)
Ch3	-0.02	-0.008	0.01	0.02	-0.02	-0.02	-0.04
	(-1.59)	(-0.69)	(0.38)	(1.77)	(-2.10)	(-2.10)	(-2.71)

Notes: Ch1= 1 child below 18, Ch2= 2 children below 18, Ch3= more than 2 children below 18. R1 = Stockholm, R2=Gothenburg/Malmö, R3= major towns, R4=southern areas, R5= major towns northern areas.