The analysis of the relationship between household expenditure level and embodied pollution: a methodological note

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Abstract:

The study of the relationship between household expenditures and environmental pressures has become a question of major importance, since household consumption causes directly and indirectly the greatest demand of natural resources and the majority of environmental impacts. From the 1970's, several authors have analysed total energy and/or atmospheric emissions associated to household consumption applying input-output analysis. The aim of this paper is to discuss a specific methodological problem that different authors have dealt with in different ways, which could affect the outcomes. Households are non-homogeneous units; they have different number of members and/or with different ages. This fact raises a problem of comparison when the purpose is to order households according their relative "economic position" using as indicator their expenditure level. In this paper we describe the different alternatives applied by previous studies and we discuss some strengths and weakness of each methodological option. We apply all the methods to analyse the relationship between Spanish household expenditures and nine atmospheric emissions in 2000. Finally, we compare the results obtained.

Keywords: Input-Output analysis; Consumption patterns, Atmospheric pollution, Methodological analysis.

J.E.L. classification codes: C67, D12, D57.

1. Introduction

Household consumption causes directly and indirectly the greatest demand of natural resources and the majority of environmental impacts generated by any society (United Nations, 2007).[1] Consequently, a question of major importance and interest is to study how different households contribute to environmental pressures. This question can be analysed from different perspectives since lifestyles are influenced by several variables (Duchin, 1998). However, one of the most important variables is, without doubt, the level of household expenditures (Pachauri, 2004; Lenzen *et al.*, 2006).

The study of the relationship between expenditures and environmental pressures is relevant to analyse the relative responsibilities of different households on these environmental pressures, as well as, to forecast how environmental policies aimed at reducing such pressures can affect households depending on the expenditure level. Moreover, this kind of studies can also be useful to go deeper on knowing how changes in composition of consumption might contribute to a "delinking" between per-capita income growth and environmental pressures when income and consumption levels grew, as the so-called Environmental Kuznets Curve hypothesis postulates (Roca, 2003).

Since household consumption generates environmental pressures directly and indirectly, the most appropriate approach is the so-called input-output analysis. Such methodology allows for calculating not only the total production that each unit of money spent in the different types of goods and services swept away, but also the linked environmental pressures. In the particular case of household consumption, the traditional environmental input-output model can also incorporate microdata from

[1] In fact, even the most of emissions linked to the production of investment goods could be associated to present and future household consumption if we take into account that the production of household consumption goods and services requires to make capital fix investment.

consumer expenditure surveys improving the quality and the detail of results. This approach was adopted by Herendeen and Tanaka (1976). In this seminal work they studied the relationship between expenditure and income levels and total requirements of energy of different households in the USA in 1960. In the last decades, several authors have applied the same methodology for different countries and years. These studies basically analyse how the energy and/or emissions associated to household consumption change when the level of household expenditure[2] increases. Some of these works are Herendeen (1978) for energy in Norway, 1973; Herendeen *et al*. (1981) for energy in USA, 1972-73; Peet *et al*. (1985) for energy in New Zealand, 1974-1980; Vringer and Blok (1995) for energy in the Netherlands, 1990; Lenzen (1998) for greenhouse emissions in terms of CO_2-equivalent in Australia, 1993-94; Wier *et al*. (2001) for CO_2 emissions in Denmark, 1995; Peters *et al*. (2004) for CO_2; SO_2 and NO_x emissions in Norway, 2000; Lenzen *et al*. (2006) for energy in Australia, Brazil, Denmark, India and Japan, 1994-95; Roca and Serrano (2007) for nine atmospheric gases in Spain, 2000; and Kerkhof *et al*. (2009) for greenhouse, acidification gases and eutrophication pollutants in the Netherlands, 2000. Obviously, the results of these different studies are not identical, but there is a common conclusion in the majority of them: energy and emissions increase with the level of expenditure and the increase is slightly less than proportional.

However, the purpose of this article is not to analyse and compare the outcomes of these different articles, but to discuss a specific methodological problem that different authors have dealt with in different ways, which might affect the outcomes.

[2] Some authors also consider the relationship between income level and energy or emissions but the usual variable is expenditure. One of the reasons of using expenditure instead of income is that expenditure household surveys are more reliable for expenditure data that for income data even when this last data is provided.

The cause of the problem is that households are non-homogeneous units; they usually have different number of members and/or with different ages. This fact raises a problem of comparison. In other words, if the purpose is to order households according their relative "economic position" using as indicator their expenditure level, one could convincingly argue that a two-member household that expends the same amount of money as a four-member household might have, in fact, much more "level of consumption". Hence, the aim of this study is to present the different alternatives applied by previous studies to get a better understanding of the strengths and weaknesses of each methodological option.

The next section describes the different alternatives considered. In Section 3, we apply the five different methods described in the previous section on the same case, the relationship between Spanish household expenditures and nine atmospheric emissions in 2000. We compare and analyse the results obtained. Finally, some final comments and conclusions are presented.

2. The household size and the ordering of household according their level of expenditure

As mentioned above, several authors have analysed how the energy and/or emissions associated to household consumption change when the level of household expenditure increases. The data reported by household expenditure surveys give information about households which are different in size and composition. So, how this issue might be approached when we order households by expenditure level?

The first alternative is obviously to avoid the problem and classify households according their absolute or total expenditure level independently their demographic characteristics. In the previous example of two-member household that expends the same amount of money as a four-member household; both households would be classified into the same group. In our opinion this is not a satisfactory option for those studies that use explicitly or implicitly the level of expenditure as an indicator of relative position in consumption or affluence.

A second alternative involves grouping households according to their size and then performing a “disaggregated analysis” on each group. This simple alternative presents a basic disadvantage: we cannot estimate synthetic indicators –such as unique elasticity values– or synthetic graphics for the global relationship between household expenditure and energy or emissions. On the contrary, we will have as many indicators or graphs as household size groups we had considered in the study. Obviously, if we were specifically interested in analysing one specific type of households (for instance, single households) or we were interested in comparing groups of households of different size, this disaggregated approach should be appropriate.

A third alternative is to divide total expenditure of each household by the number of household members. In this case, we analyse per capita-expenditure and per-capita energy or emissions. This alternative is also very simple to apply but we should be aware of the problem this alternative implies. In that case a four member-household expending double than a two member-household would be classified into the same group, although the former might have, in fact, more “level of consumption” due to the household economies of scale in consumption.

The fourth alternative is to construct equivalent consumer units, weighting each household according to the number of members (and perhaps their respective ages).[3] This alternative is the usual way to deal with the problem of comparing different households in the studies on income (or expenditure) distribution. Various mathematical transformations can be applied, each one yielding different 'equivalent consumer units'; generally, the first adult person counts 1, additional adults count less than the first, and children count less than adults. Probably, the OECD scale and the modified OECD scale are the most applied in international studies.[4] The respective weights in these scales are 1 for the first adult, 0.7 (0.5) for additional adults, 0.5 (0.3) for children. The strength of this method is its capacity to handle questions about household size and also age composition. However, there is not a consensus about the value of parameters; it might well be argued that the choice of specific parameters would be quite arbitrary. Different hypotheses on economies of scale in consumption and on necessities of monetary expenditure to meet the consumption needs of children (which, for instance, might depend on facts such as the public provision of kind gardens) would imply different specific parameters.

Lastly, a fifth alternative is to consider that household energy or emissions are function of household expenditure and also of other characteristics, mainly demographics, performing a multivariate regression. This approach has the advantage – as the disaggregated approach– of the fact that it isolates the specific role of expenditure without adopting any arbitrary assumption about the importance of economies of scale.

[3] The theoretical idea in calculating "consumer equivalent units" is to translate the expenditure of a household into the expenditure that one (adult) member household would require for obtaining the same utility. However, this idea is problematic. Household has not utility; the preferences can be associated to individuals but not to a collective. For the utility of an individual is relevant the expenditure of the household he or she belongs but also the distribution of this expenditure (Browning *et al*., 2004).
[4] EUROSTAT recommends to use the modified OECD scale for European Union countries because it considers that the OECD scale underestimate the economies of scale in consumption (Moreno, 2004).

However, we need to make additional decisions. For instance, we should decide whether we will consider only the household size or we also will differentiate age groups; if we do not consider age differences, we were implicitly assuming that household size is relevant while the age composition is not. Moreover, we also need to decide a specific functional form in the relationship between demographic characteristics and household energy or emissions.

Figure 1 synthesizes which of the previous alternatives were adopted in different articles.

Figure 1 around here

Considering the diversity of options, an important question is to known whether adopting a specific approach could lead to different outcomes. In next section we illustrate this empirical question for the case of several atmospheric pollution gases in Spain.

3. An empirical example: the expenditure elasticity of atmospheric emissions in Spain

In Roca and Serrano (2007) we applied an input output approach combining information from the Spanish NAMEA system and from the Spanish Household Budget Continuous Survey (HBCS) in order to estimate the emissions directly and indirectly linked to the consumption of each household for the year 2000. As in that paper, in this section we consider 9,628 different households and nine different gases: the six greenhouse gases regulated by Kioto protocol (CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs) and three other gases (SO_2, NO_x, and NH_3). As we did in that paper, we group the SF_6, HFCs, and PFCs gases into the so-called ‘greenhouse synthetic gases’ and we also present the total emissions of the six greenhouse gases using CO_2 equivalent units (IPCC, 1997).[5]

Results could be presented either graphically (plotting emissions and emission intensities) or calculating the expenditure elasticity of emissions as a synthetic quantitative indicator. Both the graphs and the quantitative indicator are directly connected since an increasing function of emissions means a positive elasticity; and an increasing (decreasing) function of emission intensities implies an elasticity higher (lower) than one. For the sake of clarity and simplicity to compare the outcomes of the five different alternatives, however, in this paper we present only the elasticity of emissions of each approach.

For each gas, the elasticity β -which we assume is constant- is defined according to the equation:

$$E = \alpha C^{\beta} \qquad (1)$$

where E means household emissions and C means household expenditure. This expression lends itself easily to linear regression analysis; hence, we estimate the expenditure elasticity of emissions for the first four alternatives applying the ordinary least-squares method to:

$$\ln E = z + \beta \ln C \qquad (2)$$

where C and E will take different values depending on the alternative applied. In the first alternative we will consider the total expenditure (and emissions) of each household without any correction. In the second alternative, after grouping households

[5] See Roca and Serrano (2007) for a description of the Spanish data set and the assumptions and procedures adopted.

into five groups according to their size –i.e. households composed by one, two, three, four, or more members– we perform the linear regression to each group taking into account the total expenditure. In the third alternative we will consider per-capita expenditure (and emissions). And in the fourth alternative we will consider equivalent expenditure (and emissions) according the modified OECD scale.

In the case of the fifth alternative, however, we perform a multivariate regression assuming the functional form used by Wier *et al.* (2001) and Lenzen *et al.* (2006):

$$\ln E = z + \beta \ln C + \gamma N \qquad (3)$$

where N means the number of household members, and γ is the relationship between the variation of household size and emissions. In this case, per-capita expenditures were considered.

Table 1 shows the expenditure elasticity of emissions for the nine gases considered and total of greenhouse gases in CO_2 equivalent units for Spanish households in 2000. Assuming constant elasticity, a positive value of β means that emissions increase with expenditure; and β will be higher (lower) than one if the intensity of emissions (emissions by euro expended) increases (decreases) with the level of expenditure.

Table 1 around here

From the results of table 1 we reach some conclusions for the case of Spain. On the one hand, we would say that the first alternative, which uses non-corrected data, seems to be the worst option. For the most part of the gases the value of the elasticity is not in the range of values of the second alternative (different household groups attending their size or the disaggregated approach). That is the β values might be biased, in our case they would overvalue the "effective" elasticity.

Regarding the other three alternatives –i.e. the third that considers per-capita expenditure, the forth that considers equivalent expenditures, and the fifth that performs a multivariate regression–, we can say that the three alternative give very similar values and in all of them and for all the gases the value of β is in the range of the disaggregated values.

The general conclusion for CO_2 emissions follows the majority of works: when household expenditure increases CO_2 associated emissions also increase but slightly less than proportionally. For other gases –generally, not considered in the most part of other works–, the elasticity is also faintly less that one for NO_x and SO_2; and a little lower in the case of the gases more linked to agricultural and cattle activities (CH_4, N_2O, and NH_3). The greenhouse "synthetic gases" is the only case we find elasticity higher than one.

4. Conclusions

From the empirical outcomes for Spain we would tend to conclude that it seems justified to "correct" data to obtain a better approximation for the "effective" (it is to say, isolating the effect of different household size) relationship between a higher household consumption and the emissions associated. However, regarding the different alternatives that "correct" data, it gives the impression that it is not very important which of these alternatives is adopted since they present very similar outcomes. These conclusions could be or not a very specific result for Spain; hence, it would be interesting to have similar analysis for other countries. We think that this issue might be especially relevant in the next future when the number of studies about the relationship between household expenditure and environmental pressures will have probably increased. Thus, it would be interesting to known whether the outcomes for different countries and years can be compared or, on the contrary, they could be very sensible to the specific approach adopted to tackle the fact households differ in size and composition.

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Figure 1: Approach adopted in analysing the relationship between household expenditure and energy or emissions embodied in household consumption is several articles.

	Methodological approach and number alternative in brackets
Herendeen and Tanaka (1976)	Total expenditure (1st) Disaggregated analysis from 1 to 6 and more members (2nd)
Herendeen (1978)	Total expenditure (1st) Disaggregated analysis from 1 to 6 and more members (2nd)
Herendeen *et al*. (1981)	Total expenditure (1st) Disaggregated analysis of 1, 3 and 5 members (2nd)
Peet *et al.* (1985)	Total expenditure (1st) Per-capita expenditure (3rd)
Vringer and Blok (1995)	Total expenditure level (1st) Disaggregated analysis from 1 to 4 members (2nd)
Lenzen (1998)	Total expenditure (1st) Disaggregated analysis from 1 to 6 members (2nd)
Wier *et al.* (2001)	Total expenditure (1st) Equivalent consumer units using modified OEC scale (4th) Multivariate regression analysis (5th)
Peters *et al.* (2004)	Total expenditure (1st) Disaggregated analysis from 1 to 5 members (2nd)
Lenzen *et al.* (2006)	Total expenditure (1st) Multivariate regression analysis (5th)
Roca and Serrano (2007)	Total expenditure (1st) Equivalent consumer units using modified OECD scale (4th)
Kerkhof *et al.* (2009)	Equivalent consumer units using Dutch equivalent factors (4th)

Source: Own elaboration.

Table 1: Different alternatives to estimate expenditure elasticity of emissions linked to household consumption. Spain, 2000.

	1st alternative	2nd alternative					3rd alternative	4th alternative	5th alternative
	non corrected total expenditure	1 member	2 member	3 member	4 member	>4 member	per-capita expenditure	equivalent expenditure	Multivariate regression
CO_2	0.99	0.96	0.93	0.89	0.86	0.91	0.88	0.91	0.93
CH_4	0.84	0.76	0.72	0.71	0.70	0.71	0.72	0.71	0.74
N_2O	0.88	0.83	0.79	0.77	0.77	0.77	0.78	0.78	0.80
Synthetic gases*	1.10	1.09	1.12	1.13	1.12	1.08	1.08	1.11	1.11
Total in eq_CO_2	**0.98**	**0.94**	**0.91**	**0.87**	**0.85**	**0.89**	**0.86**	**0.89**	**0.91**
SO_2	0.88	0.85	0.85	0.86	0.86	0.89	0.89	0.86	0.87
NO_x	0.98	0.94	0.89	0.85	0.82	0.87	0.84	0.87	0.90
NH_3	0.85	0.77	0.72	0.70	0.69	0.70	0.71	0.71	0.74

Source: Own elaboration.