Atmospheric Pollution and Consumption Patterns in Spain: An Input-Output Approach

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Summary

This paper analyses the relationship between Spanish household consumption patterns and atmospheric pollutant emissions in 2000. Applying an input-output approach we estimate the relative responsibility of different types of households in the emissions of nine different atmospheric pollutants: the six greenhouse gases (CO2, CH4, N2O, SF6, HFCs and PFCs) regulated by the Kyoto protocol and three other gases (SO2, NOx and NH3). We combine input-output tables, national consumer survey statistics and environmental pollution satellite accounts into an environmental extended input-output model. We also analyse the assumptions required in order to apply the model to available data. We find that there is a positive and very high relationship between the level of household expenditure and the direct and indirect emissions generated by household consumption. However, the emission intensities tend to decrease with the expenditure level for the different atmospheric pollutants, with the exception of the synthetic greenhouse gases (SF6, HFCs and PFCs).

Keywords: Input-Output Analysis, Consumption Pattern, Atmospheric Pollution

JEL Classification: C67, D12, Q53

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1. Introduction: household consumption expenditure and environmental pressures

Since the early nineties, the debate on the environmental effects of economic growth has been strongly influenced by the *Environmental Kuznets Curve* (EKC) hypothesis, which states that an inverted U relationship can be found between environmental pressures and per capita income: economic growth initially has negative environmental effects, but once a critical level of per capita income has been reached the environmental situation improves as per capita income increases (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992). However, while empirical evidence of the decrease in some environmental problems in rich countries has been reported, none of the pollutants considered have been shown to unequivocally follow the evolution predicted by the EKC hypothesis (Ekins, 1997; De Bruyn and Heintz, 1999; Stern and Common, 2001; for the case of atmospheric pollution in Spain, see Roca *et al.*, 2001). Many authors claim that the hypothesis could be appropriate only in the case of pollutants with local and short-term effects and with relatively low costs of mitigation, such as SO_2, whereas emissions would tend to monotonously increase with the level of income for those pollutants with more global and long-term effects and for which reduction is more complicated, such as CO_2 (Roca, 2003).

The EKC hypothesis not only maintains that economic growth can coexist with a reduction in the environmental pressures generated by the rich countries, but it also affirms that per capita income growth is the main determinant of this decline in environmental pressures. If other factors did not change, a given degree of economic growth would result in an equivalent increase in environmental pressures; in fact, this is not the case and it could exist a "delinking" between economic growth and environmental pressures. This "delinking" would necessary imply technological changes and/or changes in final demand structure.[1] Moreover, applying De Bruyn and Opschoor's (1997) relevant differentiation, we should distinguish between absolute (or strong) and relative (or weak) delinking between economic growth and environmental

[1] In an open economy the "delinking" could also be due to the importation of pollutant intensive commodities. In this case, however, it was not a "genuine" delinking, but only a displacement of environmental costs (Arrow *et al.*, 1995, Stern *et al.*, 1996; Suri and Chapman, 1998; Muradian and Martínez-Alier, 2001).

pressures. In the first case, we had an absolute reduction in environmental pressures; in the second one, we only had a reduction in environmental pressures per unit of income.

In the literature, it is distinguished three possible factors that explain the EKC hypothesis, i.e. technological change, final demand structure, and individual preferences. However, in this paper we analyse only one of these changes, i.e. changes in final demand structure. Specifically, we only analyse one of the components of final demand, although the most important one: household consumption expenditure. The purpose of this paper is to known the relationship between environmental pressures and household consumption when households are wealthier and their consumption increases taking into account that this increase is not homothetic, i.e. the consumption structure changes whereas the consumption level increases.

In recent years, there has been an increasing interest in measuring the environmental effects of household consumption patterns. This involves studying the relative responsibility of different household-types for generating certain environmental pressures. Herendeen and Tanaka (1976) and Herendeen *et al.* (1981) are seminal works examining the "energy cost of living" for different types of household in the USA. These studies take into account not only the direct demand for energy products but, more importantly, the indirect energy requirements, i.e. the energy used to produce and distribute the commodities demanded by households. Other articles have examined the same issue in other countries, taking into account not only energy but also the associated CO_2 emissions. Some of these studies include Herendeen (1978) for Norway; Peet *et al.* (1985) for New Zealand; Vringer and Blok (1995) for the Netherlands; Wier *et al.* (2001) for Denmark; and Lenzen *et al.* (2006), which reports the outcomes of household energy requirements for five countries – i.e. Australia, Brazil, Denmark, India and Japan. In all these studies, the methodology used for computing indirect energy or indirect emissions is based on input-output analysis.

In the same line of these previous studies, we analyse the impact of different Spanish households on atmospheric pollution in 2000. The importance of this study lies in the fact that, as far as our knowledge, this is the first analysis of environmental pressures and household consumption patterns for Spain. Moreover, previous studies for other countries have tended to examine only CO_2 emissions related with energy use and here we consider nine gases. These gases are the six greenhouse gases regulated by the Kyoto protocol -carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)[2]- and three gases associated with local and regional environmental problems - sulphur oxides (SO_x measured in units of SO_2 equivalent), nitrogen oxides (NO_x) and ammonia (NH_3). Thus, the approach used in this paper to study the atmospheric pollution effects of increasing household expenditure is not a longitudinal study, but a comparative static analysis. The empirical results are very relevant to the EKC debate, even though it is obvious that this paper does not seek to test the existence of an EKC in Spain.

The rest of the paper is as follows. In Section 2 we develop an environmental extended input-output model. In Section 3, we describe the data base and explain the procedures and data preparation required to apply the model. In Section 4, we present the empirical results. And in Section 5, we offer some conclusions. Finally, in Appendix some technical details about the data preparation are given.

2. Atmospheric emissions generated by households: the theoretical model

In analysing the emissions generated by the household consumption we should consider both direct (E^{direct}) and indirect ($E^{indirect}$) household emissions. The former are the emissions produced by the household's direct consumption; the latter are the emissions associated with the production of the goods and services acquired by households.

[2] Henceforth, we consider the three last greenhouse gases (SF_6, HFCs and PFCs) as one specific group. We refer to this group as the "*synthetic gases*".

Figure 1: Direct and indirect emissions from household consumption expenditure

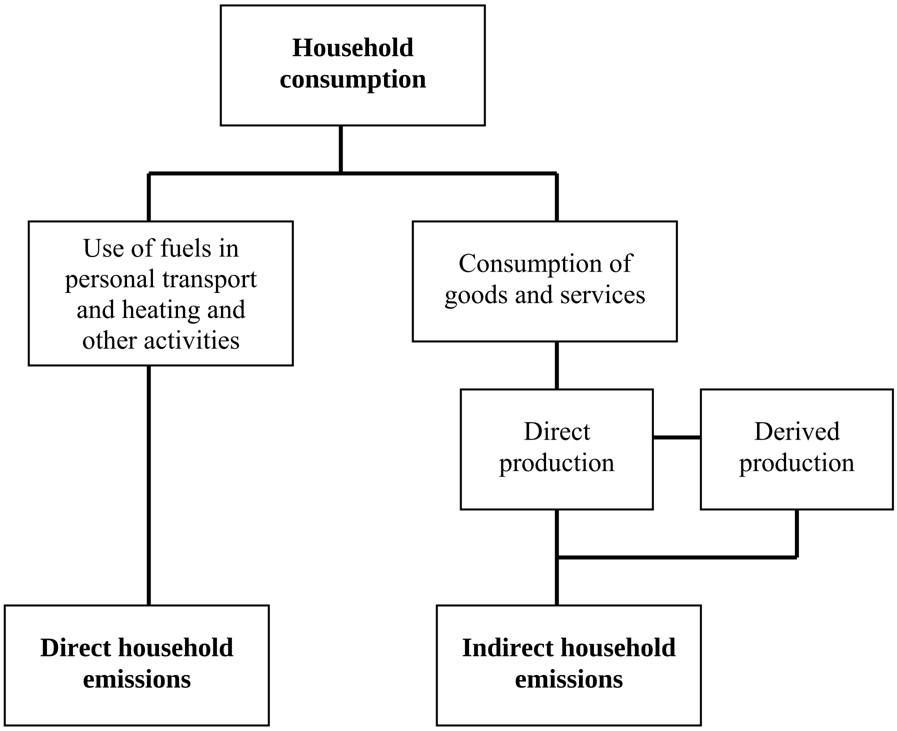

Figure 1 illustrates both processes of household emissions. Direct household emissions are due to several activities that provoke emissions, such as using combustibles to travel by car or using natural gas to cook. In general the matrix of emissions of the *k* different atmospheric pollutants for each *h* household E_{kxh}^{direct} would be calculated by applying the following expression:

$$E^{direct} = P * S \tag{1}$$

Where P_{kxd} is a matrix that represents the coefficient of emissions of the different *k* atmospheric pollutants by unit of activity *d*, and S_{dxh} is a matrix that shows the level of pollutant activities (for instance, litres of gasoline consumption or m^3 of natural gas consumption) of each household.

By contrast, to calculate indirect emissions it is necessary to use an input-output approach. Formally, for an economy of *n* sectors the standard input-output model is represented by the following expression:

$$q = (I - A)^{-1} y \quad (2)$$

where q_{nx1} is gross output vector, y_{nx1} is final demand, A_{nxn} is matrix of technical coefficients and I_{nxn} is the identity matrix. The elements of the Leontief inverse matrix, $(I - A)^{-1}_{nxn}$, capture both the direct and indirect effects of any change in the exogenous final demand vector. This expression (2) can easily be extended to account for *k* atmospheric polluting emissions. So, let V_{kxn} be a matrix of direct air emission coefficients whose *lj* element is the amount of pollutant *l* generated per monetary worth of industry *j*'s output. Thus, the level of atmospheric emissions g_{kx1} associated with a given vector of total outputs can be expressed as:

$$g = Vq \quad (3)$$

or as a function of final demand as:

$$g = V(I - A)^{-1} y = Fy \quad (4)$$

where F_{kxn} is the total emission intensity matrix, which depends on both V_{kxn} and the Leontief inverse.

This expression can be used to analyse the emissions generated by the economy as a whole or by one component of aggregate demand - such as household consumption or exports. But this expression can also be applied to calculate the emissions generated by the consumption of an individual household. In this paper, see Section 3.2, we adopt this approach to estimate indirect emissions of household consumption.

3. Atmospheric emissions generated by households in Spain: from theoretical model to empirical application

3.1. Data base

In order to adapt empirical information to the theoretical model, we have to use two very different sources: the Spanish National Accounting Matrix including

Environmental Accounts (NAMEA) and the Spanish consumer survey (*Encuesta Continua de Presupuestos Familiares* - ECPF).

In the NAMEA framework environmental information is compiled so that it is compatible with the presentation of economic activities in national accounts. In this way, the National Accounting Matrix (NAM) can be extended to include Environmental Accounts (EA), usually expressed in physical units.

The System of Economic and Environmental Accounts (SEEA) considers two types of NAMEA accounts: *hybrid supply and use tables* (HSUT) and *hybrid input-output tables* (HIOT).[3] The former consist of a pair of tables, one showing those industries that supply commodities (supply or make table), the other showing economic units that use them (use table). In this case, industries are classified according to General Industrial Classification of Economic Activities within the European Communities (revision 1) (NACE), whereas commodities follow Classification of Products by Activity (CPA). In the second type, a symmetric input-output table results from the transformation of the supply and use tables so that each industry represents one particular homogeneous type of good or service. In the case of Spain, the NAMEA system is organised in accordance with the HSUT structure (INE, 2006).

The Spanish NAM has been compiled for the period 1995-2000 in both current and basic prices and includes 110 CPA products, 72 NACE industries and several final demand categories. At the same time, the air emission EA gather information about the emissions of the pollutants produced by 46 NACE industries and households. The former are emissions resulting from the production of goods and services, whereas the latter are produced by transport, heating and other household activities.[4] At the moment,

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[3] The term *hybrid accounts* indicates that monetary and physical data are included in the same accounting framework, and at the same time differentiates them from the physical input-output accounts (see Hoekstra and Van den Bergh, 2006). Elsewhere, this term is sometimes applied to "energy input-output tables" in which certain flows between economic units are expressed in energy units rather than in monetary units (Casler and Willbur, 1984).

[4] In line with the NAMEA framework and National Accounting principles, air emissions due to incineration and decomposition of waste in landfills (principally CH_4) are included within NACE 90 (*Sewage and refuse disposal, sanitation and similar activities*). However, such emissions might be considered separately from industry and household emissions. In this paper, in line with the Dutch NAMEA experience (Keuning *et al.*, 1999), we distinguish three sources of atmospheric pollutants: "industries", "households" and "other sources", and we include CH_4 emissions from waste management in this final category.

the Spanish NAMEA does not distinguish the different activities that are responsible for direct household emissions.

The second source we have used for our analysis is the ECPF. The ECPF provides several information on Spanish households; including data on their total expenditure on consumption, expenditure on different goods and services, income, and some socioeconomic and demographic characteristics. In the ECPF goods and services are classified according to Classification of Individual Consumption by Purpose (COICOP) into 12 divisions. The sample of the ECPF is composed of approximately 9,000 households (INE, 2004).

3.2. From data to model

In order to apply the theoretical model described above, we have had to make some assumptions and solve some problems related with the data preparation.

In the case of household direct emissions, we have only information about aggregated emissions for the total of the households. Thus, from these data we must assign a level of emissions for each household of the ECPF sample. However, since the direct emissions are only important for NO_x and CO_2,[5] we only consider the direct household emissions of these two gases.

The procedure followed includes two steps. Firstly, we assume the average direct emissions for all Spanish households as the average direct emissions for the sample. Secondly, taking into account that NO_x and CO_2 are closely linked to energy use, we distribute the total emissions among the sample according to monetary expenditure on "energy products"[6] of each household:

$$E^{direct} = e^{direct} * d' \qquad (5)$$

[5] According to Spanish 2000 NAMEA data, the direct household emissions of total economy emissions represents: the 19.1% of CO_2, 1.8% of CH_4, 6.9% of N_2O, 0.7% of synthetic gases, 1.7% of SO_2, 20.7% NO_x and 1.2% of NH_3.

[6] We consider total expenditure on 4521 (natural gas), 4522 (liquefied gas), 4531 (liquid fuels), 4541 (solid fuels) and 7221 (fuels and lubricants) COICOP classes.

where E_{kxh}^{direct} is the matrix that represents the direct emissions of each household, vector e_{kx1}^{direct} are the total household direct emissions, and d_{hx1} is the vector of energy product expenditure coefficients whose elements are the expenditure in energy products of each household divided by total expenditure in energy products. In other words, with this expression we assume that one Euro expended in energy products will always generate the same direct emissions.

In the case of indirect emissions estimation, it is necessary to make some comments before explaining the procedure and data preparation. In the Spanish HSUT, emissions are allocated to heterogeneous industries, since they need to be attributed in a way that is consistent with economic data. This has significant consequences for the interpretation of environmental information. For instance, emissions associated with electricity production as an ancillary or secondary activity are, nevertheless, allocated to the particular industry that undertakes this production according its principal activity and not to NACE 40.1 (*Production and distribution of electricity*). The same principle holds true for transport emissions, which are allocated to the economic agents that perform the activities that generate the emissions. In order to apply our model we need a symmetric input-output table and we have to assign secondary productions (and associated emissions) to those industries of which they constitute the principal products. This involves rearranging the corresponding intermediate consumption and the respective atmospheric polluting emissions. In this paper, the matrices of technical coefficients A_{nxn} and direct emission coefficients V_{kxn} are estimated from INE (2005, 2006) for 46 industries in line with the "technology industry hypothesis", according to which all products from one industry are assumed to be produced with the same technology. A detail analysis is given in Appendix.[7]

It also should be noted that in the theoretical model one sector or industry correspond to only one commodity. In fact, each sector includes a great number of commodities. Thus,

[7] In fact, there are two methods, based on two different technology assumptions, which are used for combining the supply and use tables to derive the traditional input-output table. On one hand, the method based on "technology industry hypothesis", which has been applied in this paper; and on the other hand, the method based on "technology product hypothesis". The latter assumes that each product is produced with the same technology no matter the industry where it is produced. This hypothesis is economically more reasonable than the former; however, as it is usual, it has not been used in this paper because the symmetric input-output table generated has a huge number of negative coefficients, which has no sense.

the implicit assumption is that one Euro spent on one commodity will always result in the same production and pollution as another Euro spent on other commodity included in the same sector. This is a general limitation of the input-output analysis, which becomes more significant with increasing levels of aggregation in the input-output tables.

Moreover, in the theoretical model we have considered a close economy, i.e. we do not have taken into account the imports of final and/or intermediate goods or the emissions associated with. Even though these emissions are produced in other countries, household consumption is responsible for some of them. In fact, in this paper, since we estimate the emissions using the *total* technical coefficient matrix A_{nxn}, which includes both domestic and imported inputs, we take into account both types of emissions. Thus, we consider not only the emissions domestically produced by this economy but also those associated with the production of imported inputs and imported final goods and services. These foreign emissions can be interpreted in two ways. Firstly, they are actually emissions that are avoided as Spain purchases commodities abroad. And secondly, if we assume that the technologies and emission coefficients of other countries are the same as those in Spain, these emissions can be seen as the emissions effectively generated abroad in order to provide Spanish imports.[8]

Lastly, there is an important problem related with the product classification of the different data sources. That is, goods and services are classified according to different criterion in the NAMEA and ECPF data bases. Whereas the former uses the CPA, the latter uses the COICOP. Thus, in order to apply the expression (4) of the theoretical model, we need "translate" household expenditure in COICOP groups into household expenditure in CPA groups. In doing so, we use a composition matrix of aggregated commodity consumption that relates *n* CPA groups with *s* COICOP groups, i.e. the

[8] This assumption is frequent when specific knowledge of foreign technology is not available (Munksgaard *et al.*, 2000). However, the technologies employed in countries from which imports originate might differ markedly and, in fact, such a consideration is increasingly common in the literature, see e.g. Ahmad and Wyckoff (2003), Lenzen *et al.* (2004), Nidjam *et al.* (2005) and Peters and Hertwich (2006a, 2006b).

matrix M_{nxs} provided by the Spanish Statistics Office, *Instituto Nacional de Estadística* (INE).[9]

Thus, let C_{sxh} be the matrix of COICOP consumption of each household, we can estimate household indirect emissions ($E_{kxh}^{indirect}$) as:

$$E^{indirect} = V(I - A)^{-1} MC \qquad (6)$$

where $V(I - A)^{-1}$ is the total emission multiplier defined in Section 2.

Finally, total emissions of each household E_{kxh} are calculated as:

$$E = E^{direct} + E^{indirect} \qquad (7)$$

4. Empirical results

4.1. Different pollutant intensities for different goods and services

In Section 3.2, we explained how we have calculated total emissions associated with different goods and services (including NO_x and CO_2 direct emissions linked to the energy product uses). Thus, we have the pollutant intensities - i.e. the emissions for unit of expenditure - for 47 COICOP groups. However, we present our outcomes considering only 14 groups (Table 1).[10] Theses categories are the result of splitting up, on one hand, the division 4 "Housing, water, electricity, gas and other fuels" into "Housing and water", which includes all the expenditure related with housing maintenance and water supply;[11] and "Electricity, gas and other fuels". On the other hand, the division 7 "Transport" has been divided into "Personal transport", which

[9] Here *n* is equal to 46 CPA groups and *s* is equal to 47 COICOP groups.

[10] In fact the pollutant intensity of each category of goods would be different depending on how the expenditure in each group is distributed among different subcategories of goods. In this table, we have supposed that this distribution is the same for all the sample, even though in Section 4.2 we has always considered all the different intensities.

[11] Specifically, it includes 04.1 "Actual rentals for housing", 04.2 "Imputing rentals for housing", 04.3 "Maintenance and repair of the dwelling" and 04.4 "Water supply and miscellaneous services relating to the dwelling" COICOP groups.

includes purchase of vehicles[12] and the expenses associated with the use of private car such as purchase of fuels and lubricants; and "Transport services", which includes transport by railway, road, air and/or sea. This splitting has been made in order to highlight the more pollutant COICOP products.

Table 1: Spanish COICOP products

Codes		COICOP Divisions
I	01	Food and non-alcoholic beverages
II	02	Alcoholic beverages, tobacco and narcotics
III	03	Clothing and footwear
IV	04.1 - 04.4	Housing and water
V	04.5	Electricity, gas and other fuels
VI	05	Furnishings, household equipment and routine household maintenance
VII	06	Health
VIII	07.1 - 0.72	Purchase of vehicles and operation of personal transport equipment
IX	07.3	Transport services
X	08	Communication
XI	09	Recreation and culture
XII	10	Education
XIII	11	Restaurants and hotels
XIV	12	Miscellaneous goods and services

Source: own elaboration from 2000 ECPF.

Tables 2 and 3 present the total emission intensities for the greenhouse gases and other gases, respectively. The estimations referred to Spain and for the year 2000. These tables show how the expenditure of one monetary unit in the purchase of a range of different goods and services can have very different implications in terms of the quantity and type of emissions. For instance, one Euro spent in *"Electricity, gas and other fuels"* was found to generate more than eleven times emissions of SO_2 than the average Euro spent in household consumption. This is also the most pollutant expenditure in terms of CO_2 and NO_x. Also, connected with CO_2, SO_2 and NO_x emissions, other very important pollutant COICOP group is *"Purchases of vehicles and operation of personal transport equipment"*. In contrast the most polluting goods in terms of CH_4, N_2O and NH_3 are the goods included in *"Food and non-alcoholic beverages"*, *"Alcoholic beverages, tobacco and narcotics"* and *"Restaurants and*

[12] It should be noticed that in ECPF, it is included in the current year the total amount of the expenditure on the durables goods, i.e. cars, appliances, etc. However, in economic terms it would be better distribute the total expenditure among the different years of use. In order to avoid this situation, those expenditures would be distributed among different years according to the shelf life of durable goods, but we do not have data for making this assignation.

hotels" - i.e. those groups connected with agriculture and cattle raising CPA groups. Finally, the synthetic greenhouse gases are relevant in *"Health"* - mainly due to the HCFs emissions of class *"Medical products, appliances and equipment"* - and in *"Furnishing"*.

Table 2: Total emission intensity of the Greenhouse gases of different COICOP groups, Spain 2000

Units: Index numbers, mean of total consumption expenditure of households 2000 base = 100

CO_2		CH_4		N_2O		Synthetic greenhouse gases*		CO_2 equivalent	
COICOP	*Intensity*	*COICOP*	*Intensity*	*COICOP*	*Intensity*	*COICOP*	*Intensity*	*COICOP*	*Intensity*
V. Electricity and gas	755.75	I. Food	356.21	I. Food	317.72	VII. Health	511.04	V. Electricity and gas	658.12
VIII. Personal transport	302.17	II. Alcoholic beverages	151.43	II. Alcoholic beverages	138.77	VI. Furnishings	202.72	VIII. Personal transport	263.50
I. Food	77.37	V. Electricity and gas	140.96	XIII. Restaurants	106.63	III. Clothing	161.61	I. Food	113.15
VII. Health	66.21	XIII. Restaurants	116.59	VII. Health	97.64	XIV. Other services	139.61	VII. Health	71.62
IX. Transport services	60.91	XI. Recreation	48.34	V. Electricity and gas	82.74	VIII. Personal transport	134.61	II. Alcoholic beverages	64.00
VI. Furnishings	54.05	III. Clothing	47.04	XI. Recreation	73.71	I. Food	94.35	IX. Transport services	55.73
III. Clothing	51.24	VIII. Personal transport	29.82	XIV. Other services	54.02	XI. Recreation	90.34	VI. Furnishings	53.60
II. Alcoholic beverages	50.77	VII. Health	25.58	III. Clothing	54.00	II. Alcoholic beverages	73.43	III. Clothing	52.70
XI. Recreation	48.53	XIV. Other services	25.33	VI. Furnishings	46.56	IX. Transport services	53.55	XIII. Restaurants	51.69
XIV. Other services	46.24	VI. Furnishings	24.95	VIII. Personal transport	42.74	IV. Housing and water	50.65	XI. Recreation	50.70
XIII. Restaurants	42.08	IX. Transport services	20.37	IX. Transport services	27.43	XIII. Restaurants	48.27	XIV. Other services	46.54
IV. Housing and water	37.78	IV. Housing and water	15.33	IV. Housing and water	23.45	V. Electricity and gas	42.02	IV. Housing and water	35.42
X. Communication	33.46	X. Communication	11.68	X. Communication	14.64	X. Communication	31.31	X. Communication	30.65
XII. Education	18.74	XII. Education	9.58	XII. Education	11.01	XII. Education	15.70	XII. Education	17.54

Source: own elaboration from 2000 Spanish NAMEA and 2000 ECPF.

**Synthetic greenhouse gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent.*

Note: The emissions of the six greenhouse gases measured in CO_2 equivalent have been aggregated in accordance with their global warming potential values as established by the IPCC. The conversion factors are: 1 for CO_2, 21 for CH_4, 310 for N_2O and 23,900 for SF_6. For the PFC group, values oscillate between 6,500 and 9,200 depending on the gas in question, while for the HFC group, values range between 140 and 11,700.

Table 3: Total emission intensity of the other gases of different COICOP groups, Spain 2000

Units: Index numbers, mean of total consumption expenditure of households 2000 base = 100

SO_2		NO_x		NH_3	
COICOP	*Intensity*	*Sector*	*Intensity*	*Sector*	*Intensity*
V. Electricity and gas	1124.62	V. Electricity and gas	613.98	I. Food	379.39
VIII. Personal transport	115.81	VIII. Personal transport	288.04	II. Alcoholic beverages	158.03
VII. Health	94.66	I. Food	127.47	XIII. Restaurants	121.61
I. Food	70.58	II. Alcoholic beverages	66.39	XI. Recreation	63.78
VI. Furnishings	69.17	XIII. Restaurants	53.96	III. Clothing	40.61
III. Clothing	69.02	IX. Transport services	51.43	VII. Health	37.43
XIV. Other services	67.59	VII. Health	48.76	XIV. Other services	35.36
XI. Recreation	62.77	III. Clothing	46.54	VI. Furnishings	24.01
II. Alcoholic beverages	54.16	XI. Recreation	45.82	VIII. Personal transport	15.91
IV. Housing and water	53.48	VI. Furnishings	44.17	IX. Transport services	15.54
XIII. Restaurants	52.57	XIV. Other services	36.64	IV. Housing and water	14.17
IX. Transport services	48.28	IV. Housing and water	28.89	V. Electricity and gas	11.80
X. Communication	47.84	X. Communication	25.88	X. Communication	7.11
XII. Education	31.98	XII. Education	13.88	XII. Education	6.97

Source: own elaboration from 2000 Spanish NAMEA and 2000 ECPF.

Then, we are therefore drawn to the conclusion that the differences in the composition of household expenditure could be very important when explaining the emissions generated by different households. In the following Section we analyse this question considering the differences linked to the differences in the level of expenditure.

4.2. The relationship between level of household expenditure and atmospheric emissions in Spain

As mentioned above, we are interested in analysing how emissions change when household expenditure increases, i.e. we are interested in analysing the expenditure elasticity of emissions. Households are, therefore, classified according to their level of expenditure. However, we should point out two aspects concerning such a classification.

Firstly, it might be argued that it would be more appropriate to consider the income rather than the expenditure variable; nevertheless, we have chosen to use the latter for two reasons. The first reason is that the source we have used - i.e. ECPF – provides more complete and reliable data on expenditure than on income. The second reason is that linking income and emissions taking into account only consumption expenditures could be interpreted as supposing that savings do not result in emissions when in fact investment can be as environmentally problematic as consumption, or even more so. However, classifying households according to their level of expenditure has some limitations. As it has been mentioned[13], one significant problem of this method is that the ECPF includes in the current year the total amount of the expenditure on durable goods. This fact implies that those households who have bought durable goods in the current year will be classified in the highest percentile.

Secondly, another problem for this analysis is how to arrange the different households taking into account their differences in size and composition. That is, a bigger level of expenditure could mean more household expenditure or more per capita expenditure. A possible approach is to apply some type of transformation in order to calculate the "equivalent expenditure". Even though there are other possible methods, the most usual transformation is the "modified OECD scale"[14] (Wier *et al.*, 2001; Roca and Serrano, 2007), In this paper, however, we adopt a different approach: we solve the problem of different household size analysing the expenditure elasticity of emissions not for the whole sample but for the different household groups according their size. Thus, we made independent analysis for one member households, two member households, three member households, four member households, and households with five or more members.[15]

We use microdata of 9,628 different households - classified according their size - in order to estimate the β expenditure elasticity of emissions - which we suppose constant - according to the equation:

$$E = \alpha K^{\beta} \quad (8)$$

where E means total household emissions and K means household expenditure. The estimation is based on an application of the ordinary least-squares method to:

$$\ln E = z + \beta \ln K \quad (9)$$

[13] See Section 4.1, footnote 12.

[14] This approach takes into account economies of scale in consumption and the differences between children and adults. According to this scale, the first person over 14 years represents 1 consumer unit, other persons over 14 years 0.5 units and children under 15 years 0.3 units.

[15] Vringer and Blok (1995) adopt this same approach in one of their figures (figure 7, p. 900). It should be note that this approach only considers the size of the households but not the different composition between adults and children.

The results for the different gases and different household size are presented in Tables 4 and 5.

Table 4: Expenditure elasticity of greenhouse gas emissions, Spain 2000

	1 member household		2 member household		3 member household		4 member household		> 4 member household	
	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2
CO_2	0.96	0.80	0.93	0.77	0.89	0.75	0.86	0.74	0.91	0.78
CH_4	0.76	0.56	0.72	0.62	0.71	0.61	0.70	0.62	0.71	0.68
N_2O	0.83	0.68	0.79	0.72	0.77	0.72	0.77	0.73	0.69	0.77
Synthetic gases*	1.09	0.86	1.12	0.88	1.13	0.88	1.12	0.87	1.08	0.88
Total in CO_2 eq.	**0.94**	**0.82**	**0.91**	**0.81**	**0.87**	**0.79**	**0.85**	**0.78**	**0.89**	**0.82**

Source: own elaboration.

*: *Synthetic gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent.*

Table 5: Expenditure elasticity of other gas emissions, Spain 2000

	1 member household		2 member household		3 member household		4 member household		> 4 member household	
	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2	Elasticity	R^2
SO_2	0.85	0.83	0.85	0.85	0.86	0.88	0.86	0.88	0.89	0.91
NO_x	0.94	0.78	0.89	0.76	0.85	0.73	0.82	0.72	0.87	0.77
NH_3	0.77	0.52	0.72	0.57	0.70	0.55	0.70	0.57	0.70	0.64

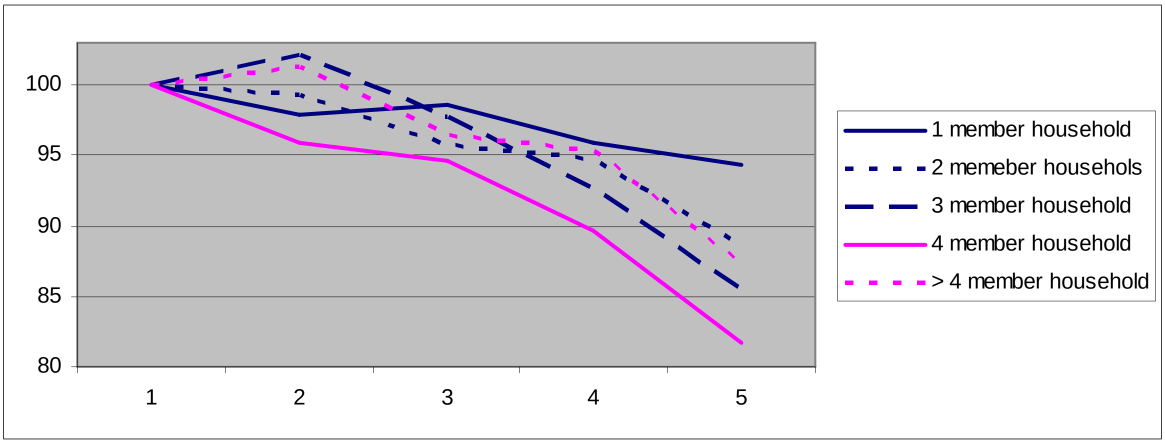
Source: own elaboration.

We can distinguish three cases. First, CO_2, SO_2 and $NO_{x,}$ emissions has an intensity with very high values but inferior to one - the values are situated between 0.82 and 0.96. Second, the lowest values are for the pollutants more connected with agriculture and cattle raising - NH_3, CH_4 and N_2O -, in this cases the values oscillate from 0.70 to 0.83. Third, the synthetic greenhouse gases have an elasticity even higher than one.

In following figures (Figures 2 - 9) we present average emissions intensity - i.e., total emissions divided by total expenditure - for the different household types classified by expenditure quintiles. These figures and the estimated elasticity are directly connected: in general we can expect an increasing or decreasing intensity depending if the elasticity is higher or lower than one.

Figure 2: Intensity of emissions of CO_2 of expenditure household quintiles, Spain 2000

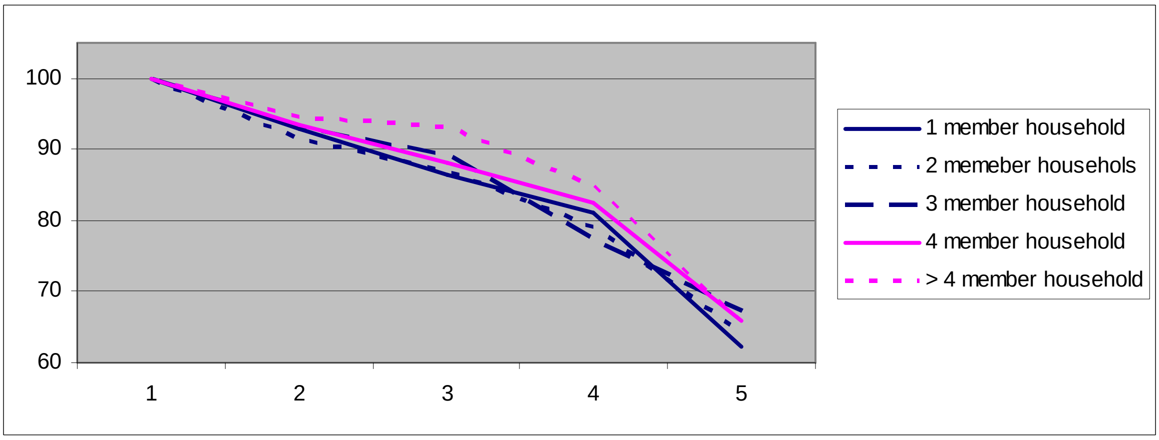
Unit: first quintile base = 100



Source: own elaboration.

Figure 3: Intensity of emissions of CH_4 of expenditure household quintiles, Spain 2000

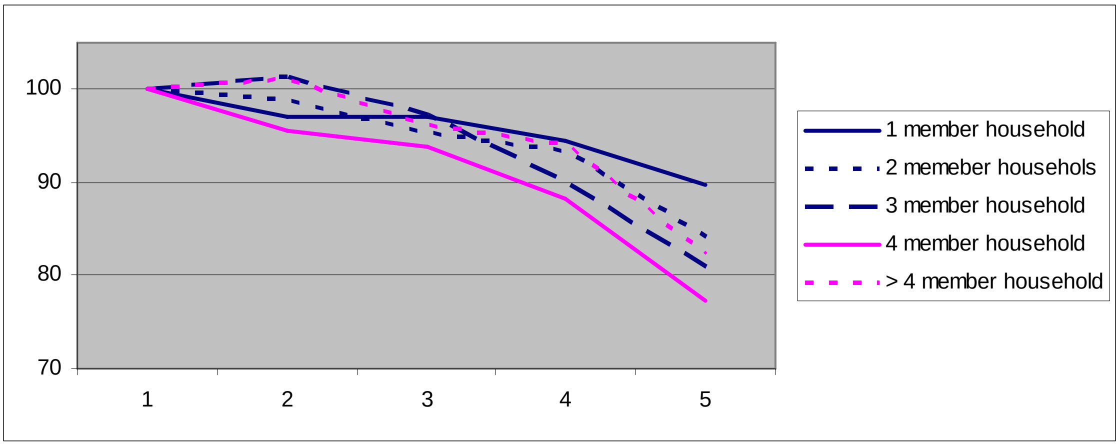
Unit: first quintile base = 100



Source: own elaboration.

Figure 4: Intensity of emissions of N_2O of expenditure household quintiles, Spain 2000

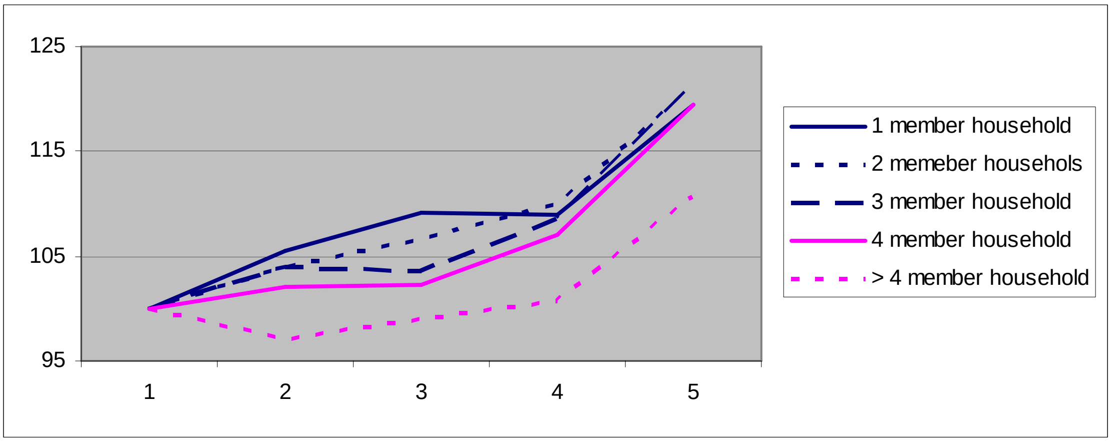
Unit: first quintile base = 100



Source: own elaboration.

Figure 5: Intensity of emissions of Synthetic greenhouse gases* of expenditure household quintiles, Spain 2000

Unit: first quintile base = 100

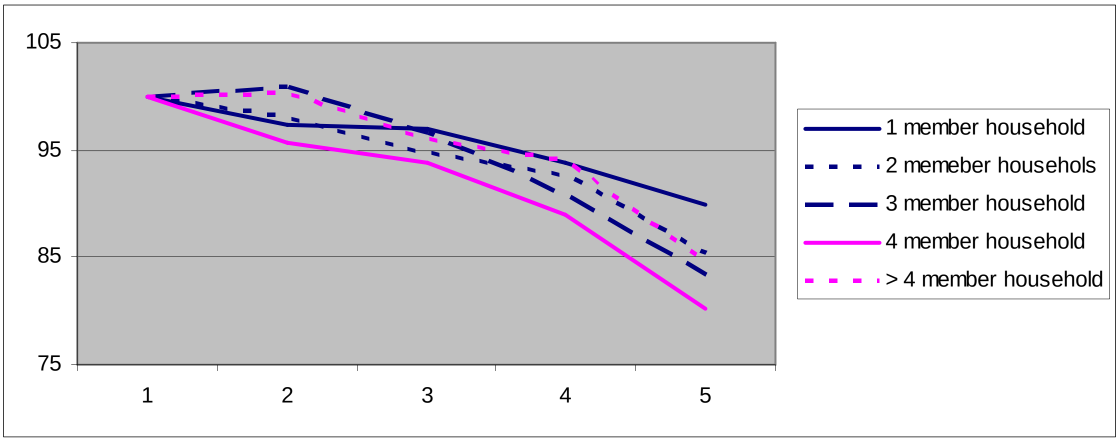


Source: own elaboration.

: Synthetic greenhouse gases are total SF_6, HFCs and PFCs emissions measured in CO_2 equivalent.

Figure 6: Intensity of emissions of Greenhouse gases* of expenditure household quintiles, Spain 2000

Unit: first quintile base = 100

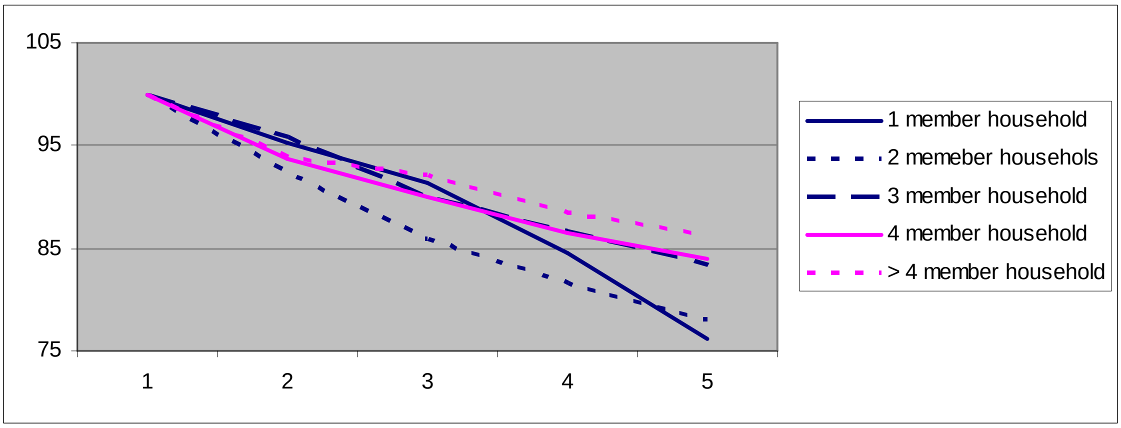


Source: own elaboration.

**: Greenhouse gases are total CH_4, CO_2, N_2O, SF_6, HFCs and PFCs emissions measured in CO_2 equivalent.*

Figure 7: Intensity of emissions of SO_2 of expenditure household quintiles, Spain 2000

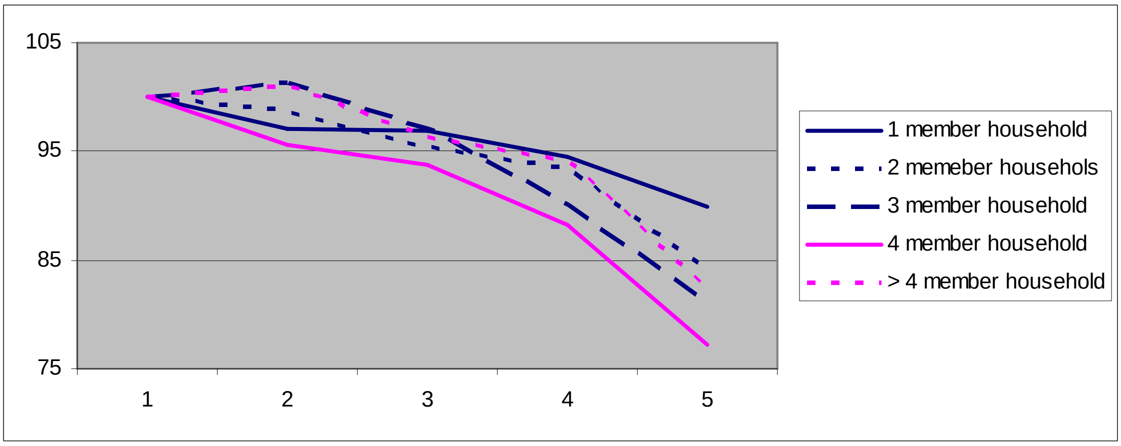
Unit: first quintile base = 100



Source: own elaboration.

Figure 8: Intensity of emissions of NO_x of expenditure household quintiles, Spain 2000

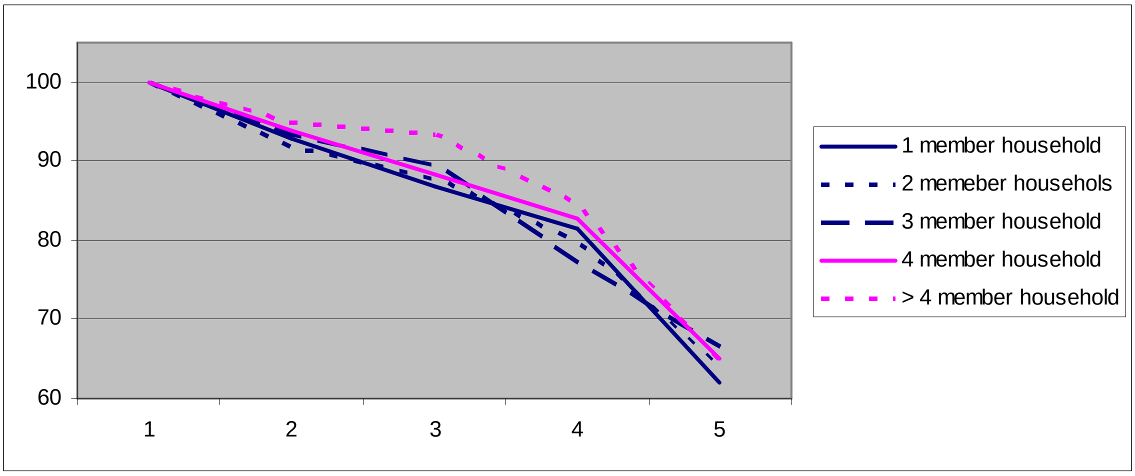
Unit: first quintile base = 100



Source: own elaboration.

Figure 9: Intensity of emissions of NH_3 of expenditure household quintiles, Spain 2000

Unit: first quintile base = 100



Source: own elaboration.

In general, we observe a decreasing intensity in all the gases and for the five types of households, with the exception of the synthetic greenhouse gases. The data of Tables 6 - 8 are useful for explaining these outcomes. These tables present the relative weight in total expenditure of selected types of commodities considering the 47 groups of COICOP. For making these tables we have considered both the pollutant intensity and the relative weight of the total expenditure of each commodity.

As we have pointed out before, in the case of CH_4, N_2O and NH_3 the "*Food*" COICOP group is the key category. For any type of household the relative weight of this group always decreases with the level of expenditure. We should point out that this group is also a key category for other gases; this is because "*Food*" has significant pollutant intensities in the most gases and it represents and important part of the household expenditure.

Table 6: Expenditure in key commodities for CH_4, N_2O and NH_3 emissions as percentage of total expenditure of each group, Spain 2000

	First quintile	Second quintile	Third quintile	Forth quintile	Fifth quintile
Food					
1 member household	23.08	20.47	18.08	16.00	9.52
2 member household	26.46	23.06	21.09	17.96	12.50
3 member household	24.02	21.30	19.66	15.59	12.72
4 member household	23.37	20.69	19.07	17.10	12.11
> 4 member household	24.44	22.65	21.62	18.65	12.40

Source: own elaboration.

In the case of "energy" emissions (CO_2, NO_x and SO_2), the question is more complex because there are two key categories. The expenditure in "*Electricity, gas and other fuels*" decreases with the level of expenditure[16], but the expenditure in "*Operation of personal transport equipment*" increases with the level of expenditure or has an inverted U form. We also should take into account, as said before, that food production is a very energy intensive activity and the emissions linked to food commodities are a significant weight in these emissions.

[16] Moreover, the relative expenditure decreases with the number of household members; in other words, it seems there are some "scale economies" in the use of residential energy.

Table 7: Expenditure in key commodities for CO_2, NO_x and SO_2 emissions as percentage of total expenditure of each group, Spain 2000

	First quintile	Second quintile	Third quintile	Forth quintile	Fifth quintile
Electricity, gas and other fuels					
1 member household	5.83	5.23	4.70	3.77	2.40
2 member household	5.82	4.75	3.92	3.33	2.55
3 member household	4.68	4.08	3.46	2.97	2.20
4 member household	4.37	3.66	3.21	2.72	2.12
> 4 member household	3.98	3.25	3.06	2.57	2.14
Operation of personal transport equipment					
1 member household	0.27	0.60	1.30	2.47	3.75
2 member household	2.23	3.85	4.48	5.10	4.50
3 member household	5.15	6.36	6.55	6.16	5.03
4 member household	6.24	6.72	7.09	6.45	5.17
> 4 member household	6.24	8.08	6.98	7.77	6.29

Source: own elaboration.

For the synthetic greenhouse gases the question is more complex because the relation between emissions and commodity groups is more dispersed. The groups selected as key categories are: "*Purchase of vehicles*", "*Clothing*", "*Medical products*, *appliances and equipment*", "*Personal care*", and "*Goods and services for routine household maintenance*". Looking at these groups it is not easy to conclude a clear trend in the relation of expenditure relative weight and total expenditure. The only exception is the first one, "*Purchase of vehicles*", characterized by a clear concentration of expenses in the fifth quintile; it explains the increase of synthetic greenhouse gases emissions for this quintile (see Figure 5). As mentioned at the beginning of this Section, this concentration is not strange because car are the most important durable consumption good and people who buy a car in one year normally will appear in the highest quintile.

Table 8: Expenditure in key commodities for Synthetic greenhouse gases emissions as percentage of total expenditure of each group, Spain 2000

	First quintile	Second quintile	Third quintile	Forth quintile	Fifth quintile
Purchase of vehicles					
1 member household	0.02	0.02	0.20	0.45	6.36
2 member household	0.01	0.07	0.36	0.90	8.33
3 member household	0.06	0.37	0.79	3.50	13.30
4 member household	0.36	0.69	0.72	4.21	13.34
> 4 member household	0.64	1.23	2.50	4.45	12.15
Clothing					
1 member household	4.08	4.65	5.31	5.80	5.69
2 member household	4.04	5.37	6.11	6.26	6.09
3 member household	4.84	6.31	6.64	6.78	6.07
4 member household	5.69	6.36	6.92	6.88	6.18
> 4 member household	5.38	6.50	6.82	6.54	5.87
Medical products, appliances and equipment					
1 member household	1.23	1.33	1.29	1.15	0.98
2 member household	1.22	1.25	1.30	1.57	1.26
3 member household	1.35	1.41	1.27	1.24	0.95
4 member household	1.34	1.37	1.24	1.09	0.99
> 4 member household	1.74	1.31	1.13	1.12	0.94
Personal care					
1 member household	2.47	2.28	2.59	2.32	2.08
2 member household	2.12	2.33	2.26	2.10	1.92
3 member household	2.02	2.16	2.06	1.89	1.61
4 member household	1.89	1.86	1.84	1.75	1.47
> 4 member household	1.96	1.77	1.72	1.70	1.45
Goods and services for routine household maintenance					
1 member household	1.40	2.28	2.78	2.33	2.86
2 member household	1.70	1.91	1.94	1.87	2.29
3 member household	1.48	1.46	1.40	1.73	1.87
4 member household	1.45	1.54	1.39	1.66	1.98
> 4 member household	1.72	1.40	1.53	1.47	2.34

Source: own elaboration.

5. Conclusion

In this paper we have used an input-output approach and different data sources in order to analyse the relationships between levels of household expenditure and associated atmospheric pollution in Spain. We have estimated the expenditure elasticity of emissions of different gases.

In connection with the EKC debate, we can say that a positive elasticity significantly lower than one could be used as an argument to justify a relative delinking between increasing consumption and emissions, but it would be not sufficient to expect an absolute delinking. Obviously, it could be other factors that have not been considered in this paper - such as technological changes -, which may explain an absolute delinking for some gases along the time. Even though it is not the aim of this paper, we can stand that in the case of Spain there is not any evidence of this trend for the majority of gases (Roca *et al.*, 2001; Roca and Serrano, 2007).

We have certainly estimated an expenditure elasticity lower than one for the majority of gases. But in general, according to our results when expenditure increases the emissions will increase in a very similar percentage. For instance, a 10% in the increase of expenditure would approximately be associated with an average increase of total greenhouse emissions situated between a 8.5% and 9.4% depending on the household size. Thus, the structure expenditure changes due to expenditure increases could only explain a very low “relative delinking”.

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APPENDIX: Commodity-by-commodity hybrid input-output matrices according to industry technology hypothesis

Let us adopt the following annotation for n commodities, m industries and k atmospheric pollutants:

U_{nxm} is the use matrix whose ij th element represents the amount of commodity i consumed by industry j measured in monetary units.

M_{nxm} is the supply or make matrix whose ij th element represents the amount of commodity i produced by industry j measured in monetary units. The transpose of the make matrix is expressed by M'.

E^{I}_{kxm} is the atmospheric industry emission matrix whose lj th element represents the amount of pollutant l emitted by industry j measured in physical units.

g_{mx1} is the vector of industry outputs. The diagonal matrix is expressed by $\hat{g}$.

q_{nx1} is the vector of domestic commodity production. The diagonal matrix is expressed by $\hat{q}$.

Then, according to the industry technology hypothesis we can define the technical coefficient matrix A_{nxn} as:

$$A = BD \qquad \text{(i)}$$

where B_{nxm} is the industry input requirement matrix defined as $B = U\left(\hat{g}\right)^{-1}$, whose ij th element represents the requirements of commodity i per unit of output in industry j. D_{mxn} is the commodity output proportions matrix defined as $D = M'\left(\hat{q}\right)^{-1}$, whose ji th element represents the fraction of production of commodity i that comes from industry j.

Moreover, the atmospheric emission coefficient matrix V_{kxn} can be obtained by the following expression:

$$V = V^{I} D \quad \text{(ii)}$$

where V^{I}_{kxm} is the industry emission coefficient matrix defined as $V^{I} = E^{I} (\hat{g})^{-1}$, whose *lj* th element represents the amount of atmospheric pollutant *l* per unit of industry *j*'s output.

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