
“Who pollutes more? Gender differences in consumptions patterns”

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Abstract

Recent behavioral literature shows that we can identify differences between women and men in diverse domains in a general context, such as empathy, social preferences and reaction towards competitiveness, risk aversion, etc. Regarding the environment, recent studies propose that women have more knowledge and concern about the climate change than men. In this context, however, there is little evidence to what extent these behavioral differences between women and men have been translated into consumption actions more environmental friendly. Within this approach, this paper evaluates different environmental footprints of consumption patterns of women and men. As a case study, we examine Spain during the period 2008-2013. Using data from Spanish input-output tables, environmental air accounts, and household expenditure surveys for the same period, the study give evidence that gender differences take a relevant and significant position according to Weighted Least Square regression.

JEL classification: C81, D57, Q5.

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1. Introduction

In the last decades, there have been an increasing concern about the relation between environment and economy, not only in the scientific community but also in the political arena. This global environmental concern is directly associated with the large numbers of environmental catastrophes around the world related with global environmental impacts —such as the global warming— and also with important diseases affecting the health of the population.

Recent studies analyze the contribution of specific determinants in the evolution of atmospheric pollutants. For the case of the so-called greenhouse gases (GHG), recent technological changes have contributed to reduce GHG emission in the world significantly, whereas the role played by the evolution of the final demand —both, regarding its level and its structure— goes in the other direction (Arto and Dietzenbacher, 2014).

In this context it seems important to study the contribution to different environmental impacts not only from the industry or production point of view, but also from the consumption one. Looking at atmospheric pollution, it is necessary to analyze the so-called environmental footprints generated from the private consumption of different groups of the population.

Otherwise, there is a growing interest on the part of women in environmental terms, which is supported by several studies that affirm that women are more concerned and more aware of these issues. Women play an essential role in ensuring the protection of the fragile ecosystem as for example, the efficient and sustainable management of natural resources and adapt to climate change from the most rural areas of the world as in western households.

Nowadays, women are making huge progress, where the governments are rising the women's participation when they have to make important decisions about the environment. It was even a woman, Rachel L. Carson, who redefined some foundations of the Western world and arousing environmental awareness and denounces the risks of the massive use of dangerous chemicals and ecological consciousness (Bishop, 2012). Her book, "Silent Spring"- a spring without bird song - published in 1962 generated a great impact and it was one of the first contributors to the implementation of modern environmental awareness (Carson, 1962).

However, despite the strongly increasing participation of women in the labor market and other economics spheres (Skoloda, 2009) and the importance of global and regional environmental pressures in the political arena, the different environmental impact of consumer patterns from women and men have not been analyzed yet, even though there has been an explicit call for this type of research (Zelezny, 2000; Vitell, 2003). This is why the main objective of this research is to address the next question: is the environmental impact of private consumption of women and men different? If so, what are the main variables that might explain these differences? And in particular, what is the role played by gender?

To answer these questions first, we calculated the total atmospheric pollutants embedded in the consumption patterns of one-person households (OPH) of women and men by the application of an environmental extended input-output model; and then, we implemented an econometric model considering Weighted Least Square (WLS) regression. To this aim, we built a specific database from three statistical sources provided by the Spanish Statistic National Institute —input-output tables and environmental

accounts from the Spanish National Accounts, and the microdata from the Spanish household budget survey—, and the estimation of a bridge matrix that allowed the consolidation of macroeconomic dataset with microeconomic information.

As a case study, we analyzed Spain during a six-year period —from 2008 to 2013— for 13 different atmospheric pollutants, 63 industries, and 47 COICOP products —grouped in 12 main categories—. For presentation purposes, this paper only shows results for an aggregation of the 6 GHG.

Up to our knowledge there is no literature that focuses on these points, where the differences are usually analyzed at income level and other variables of interest, but not the case of gender. It is also important to mention that many of the environmental studies already analyzed expose the differentiated environmental effects between classes, race or gender, where the poor and powerless group are whom perceive the consequences of climate change, such as neighborhoods near highly polluting industries (Bullard et al., 1997; Adeola, 2014). So, this study might contribute the existing literature by merging two groups of analyses.

Given the results, it can be inferred that gender appears as a significant variable, which allows us to conclude that women have more ecofriendly consumption patterns than men. This is justified by an extensive feminist literature, which proposes women more connected to the environment and also supports results obtained over the years about these subject. This is why we consider that it is very important at public policy levels to notice this type of differences, know who to lead environmental campaigns, know better how we consume and the differences we can find not only in gender, age, region, income and so many socio-economic variables now at our disposal.

The study is structured as follows. Section 2 provides a review of previous research addressing the relation between environment and gender. Section 3 describes the methodology. Section 4 describes the Spanish database and the needed arrangements to compute our models.. Section 5 shows and comments the most relevant results. Finally, Section 6 summarizes the main conclusions of the study.

2. Literature Review

Sustainable consumer behavior and the underlying mechanisms via which consumers make or fail to make socially and environmentally responsible choices are increasingly important topics for policy makers (Barr, 2008; Schrader and Thøgersen, 2015). The *Journal of Consumer Psychology* dedicated a special issue on ethical trade-offs in consumer decision making (Irwin, 1999). According to some studies, women are more concerned than men about social issues (Eagly et al. 2009) and particularly about the environment (Zelezny, 2000; Koos, 2011). However, the literature shows the existence of a so-called "attitude-behavior gap" or "values-action gap". In other words, there is a difference between people values about the environment and people actual behaviors. The self-declared green consumers are not equipped or motivated enough to make decisions on which issue is the most significant for each purchase and alter their purchase accordingly in UK (Defra, 2007). Hughner et al. (2007) shows as consumers have favorable attitudes hold for organic food (between 46% and 67% of the population), actual purchase behavior forms only 4–10% of different product ranges. Actually the UK's Ethical market grew just by 3.2% in 2016

(Market Report, 2017¹) But in terms of gender differences we refer to ourselves with scarce literature and studies on the subject.

The context of the purchase—including demographic, social, political, economic and psychological factors as well as temporal and ideological structuring of domestic practices—is important (Hand et al., 2007; Arce et al., 2017). Among all these variables, the income level plays a relevant and important role. Sommer and Kratena, 2016 found that the bottom income carbon footprint in per capita terms is more than 2.5 times smaller than the average per capita footprint (15.7 tons of CO₂ equivalent units); whereas the top income footprint is less than twice as large. Besides these results, the income elasticity of the carbon footprint considerably decreases when moving from bottom to top income. Studies like this one of Sommer and Kratena (2017) have their roots in the 1970's—see Hereden and Tanaka (1976) and Herenden (1978) for the United States of America (USA)—, from then the carbon footprint has been extended across the world. Some examples—among the extensive literature regarding this topic—are Hayami (1996), Shinozaki et al. (2005) and Washizu and Nakano (2010) for Japan; Lenzen (1998a, 1998b) and Lenzen et al. (2006) for Australia; Munksgaard et al. (2000) for Denmark; or Roca and Serrano (2007) and Cansino et al. (2012) and Duarte et al. (2012) for Spain. The major part of these studies analyzed the environmental impact of household private consumption usually measured by the carbon footprint associated to different consumption patterns.

However, up to our knowledge, there is not any study that considers gender differences into the analysis of environmental impacts—such as carbon footprints—of consumption patterns. This is so, even when there is empirical evidence about different preferences and/or behaviors towards private consumption regarding gender. For instance, women tended to prefer comfort foods related to snacks, such as chips, ice cream, cookies, and candy, and males tended to prefer more comfort foods, such as pasta, meat or beef, and casseroles (Wansink et al., 2003) and other types of differences (Luchs et al., 2012). Taking into account that, according to the American ecological “CleanMetrics”², all kind of meats lead the list of the most polluting foods, it seems that the analysis of carbon footprint regarding gender will be a relevant theme of analysis. Another example, came from the cosmetic and pharmacy industry, which is strongly associated with deforestation of virgin forests—such as the jungle of Indonesia that are deforested to produce palm oil—, marine contamination—since many of the products contain small plastic balls that are not trapped by the filters of the treatment plants and reach the sea directly—, and also with the micro-plastics are being to incorporated into the food chain³. Hopkins (2007) estimated that a woman can consume a daily average of 12 cosmetic products; whereas in the case of men it would be half of products.

Another branch of the literature based on gender differentiation of economic behavior, identify differences between men and women in diverse domains. Croson and Gneezy (2009) reviewed different experiments to understand the gender differentiations in risk decisions, social preferences and reaction to competition, pointing out that women are more risk averse, more sensitive to different scenarios and they are less competitive than men. Andreoni and Vesterlind (2001) showed how in a modified version of the dictator game, women are more equalizers than men. According to Eagly (2009, p. 645), masculine roles are usually “masterful, assertive, competitive, and dominant” and focus on pro-social behaviors that benefit “collections”; whereas feminine roles incline to be “communal,” defined as “friendly, unselfish, concerned

¹ See www.ethicalfinancehub.org

² See www.cleanmetrics.com.

³ See www.greenpace.org.

with others, and emotionally expressive,” and focus on pro- social behaviors in relation to others in close, dyadic relationships (Eagly 2009, p. 645). Moreover, Brough et al. (2016) found a physiological link between eco-friendliness and perceptions of femininity where it is associated green behavior with women, rather than men. They states that, in some contexts, man avoid green behaviors to appear mannish as for example when some men thought bringing a reusable bag to the store was effeminate.

Finally, Nelson (1997) proposes, from feminist literature, that the union between nature and woman is born from the moment that our society considers women a part of nature that can be possessed and despised, and as the growth of female strength goes hand in hand with the growth of environmental awareness. This is why it believes that men will remain preoccupied with more economic and "competent" issues while women could be more concerned about the environment (Davidson and Freudenburg, 1996). Movement organized mainly by women to protect forests and natural patrimony as Chipko and Kenyan Greenbelt are used as the proof that women's natural closeness to nature makes them more aware of the environmental problems than men, resulting in the ideology of ecofeminism. The ecofeminism has been defining as the ideology that discusses the hierarchies established by Western thought and revalued the terms of the dichotomy that had until then been depreciated: woman and nature (Herrero, 2015).

Despite the belief from the feminist point of view that the worsening of women in society is linked in some way with the concern of environmental problems, there are studies that support this idea and other that contradict it. On the one hand, Brody et al., (1984), George (1986), Blocker and Eckberg (2016), and more recently McCright (2010) support the idea that women are significantly more concern about such issues than men. On the other hand, Arcury et al. (1987) and Arcury and Christianson (1990) are not so clear and the difference have tended to be modest. Thus, the differences between men and women concerns vary from study to study, leaving us a no strong conclusion. Other important evidence to consider is the gender differences in environmental activities (Mohai, 2008), where ironically there exist information that women are more concern about environmental issues that men, although they are less likely to participate in political activities that men. McStay and Dunlap (1993) justify these results given that generally women have lower level of political activity. In other words, whatever is generating the low political participation of women in general, also produces it in environmental activities. Otherwise, there are some evidence of the participation of women in environmental activities (Rocheleau et al., 1996) as for example women have fought against local toxic waste disposal issues (Miller et al., 2009) and against destruction of forests (Wastl-Walter, 1996). It appears that no firm conclusion can be derived from the gender roles in environmental concerns and environmental activities and, thus, more analysis and explanations are needed in this area.

Previous studies show there still is a gap in the literature regarding environmental impact of different consumption patterns by gender. This paper aims at contributing to this field, by analyzing the different atmospheric pollutants associated with the consumption baskets of women and men in Spain during the period 2008-2013.

3. Methodology

Analyzing the difference of environmental impact due to the consumption patterns of women and men requires, first, to estimate the amount of atmospheric pollutants embedded in each consumption basket of each household of the group of study, and second, to analyze which variables are relevant to explain these differences and, particularly, the role played by gender. According to these steps, this section is divided in two parts. Section 3.1 refers to all the methodological details to obtain the results of the atmospheric footprint; and section 3.2 continue with the econometric methodology implemented for the analysis of the results.

3.1. Atmospheric footprint of a consumption basket from women and men

The environmental footprint of any environmental pressure —for instance, of any atmospheric pollutant such as the well-known carbon footprint— implies the estimation of all gases generated direct and indirectly by the private consumption on any consumption unit. In other words, we account the emissions produced directly when it takes place the combustion of any energy products —i.e. driving a car— as well as all the emissions embedded in the whole production chain of the production of each product consumed —taking into account the emissions of a product and the emissions of the inputs needed to produce such product and so on—.

Based on Roca and Serrano (2007) Indirect emissions of each consumption unit according to different g

$$\mathbf{GHG} = \mathbf{Q} \mathbf{L} \mathbf{B} \hat{\mathbf{c}} = \mathbf{M} \hat{\mathbf{c}} \quad (1)$$

atmospheric gases and p different products $\mathbf{GHG}_{gxp}$ are defined as in equation (1)⁴:

where $\mathbf{c}_{pxi}$ represents the expenditure on each of the p COICOP⁵ products from the consumption basket of each consumption unit; $\mathbf{B}_{n \times p}$ is a composition matrix of aggregated commodity of consumption that relates n CPA⁶ products with p COICOP products. Matrix $\mathbf{B}$ is essential to our analysis since it allows us to connect macroeconomic data —such as matrices $\mathbf{L}$ and $\mathbf{Q}$ — with information from microeconomic databases like vector $\mathbf{c}$. Matrix $\mathbf{L}_{n \times n} = (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse, being $\mathbf{I}$ the identity matrix of appropriate dimension and $\mathbf{A}_{n \times n}$ the matrix of total technical coefficients that represents the technology of the economy⁷. The Leontief inverse gathers all the sectoral interdependencies in the economy and its elements l_{ij} exposes the total output —direct and indirect— necessary from sector i to satisfy an extra unit of final demand from sector j . Finally, matrix $\mathbf{Q}_{g \times n}$ represents the amount of each of the g atmospheric

⁴ Matrices are indicated by bold, upright capital letters; vectors by bold, upright lower case letters; and scalars by italicized lower case letters. Vectors are columns by definition, so that row vectors are obtained by transposition, indicated by a prime. A circumflex indicates a diagonal matrix with the elements of any vector on its diagonal and all other entries equal to zero.

⁵ COICOP is the acronym of “classification of individual consumption by purpose”, it is a classification developed by the United Nations Statistics Division to classify and analyze individual consumption expenditures incurred by households, non-profit institutions serving households and general government according to their purpose.

⁶ CPA is the acronym of “classification of products by activity”, which is compatible with the “statistical classification of economic activities in the European Community” (NACE) —i.e. industries—. The acronym NACE come from the French *Nomenclature statistique des activités économiques dans la Communauté européenne*.

⁷ Each element of matrix $\mathbf{A}$ is interpreted as all inputs —i.e. both domestic and imported— from sector i per unit of product of sector j . In formal terms it is expressed as $a_{ij} = z_{ij}/x_j$, where z_{ij} are the elements of the inter-sectorial transaction matrix that describe the deliveries through industries. The application of the total technical coefficient matrix, implies the application of the so-called domestic technology assumption. For more details about the inter-sectorial model see section 4.1 for further details.

pollutants generated by one unit of product of industry n , the so-called matrix of emission coefficients⁸.

In equation (1) matrix $\mathbf{M}_{exp}$ summarize the emission multiplier effect defined as the total —direct and indirect— emissions generated by an extra monetary unit expended on each product of the consumption basket of the consumer unit.

It is important to pay attention to two issues regarding the model presented above. First, although any environmental footprint includes both direct and indirect emissions, in this study we only focused on the last one because our aim is to analyze if there is a significant difference in the environmental impact of the consumption patterns from women and men and try to explain this difference through the most relevant variables, instead of to calculate the actual footprint. Second, equation (1) is a general expression that can be applied using data from any consumption unit grouping. In this study, we will focus only on those households that are representative of women and men consumption patterns, as we will explain in section 4.

3.2. Econometric analysis

Taking into account that the atmospheric impact of different consumption patterns is calculated from a household budget survey, we present the results using a WLS regression (Magee et al., 1998). Although we obtain results for all 17 different atmospheric pollutants, we only present the results of the regression analysis of the aggregation of the six GHG embedded in the consumption basket of women and men households in Spain 2008-2013. Equation (2) represents this regression, which allows us to consider the weight in the sample of each household to obtain conclusive results for the entire population:

$$GHG = \beta_1 RNUTS + \beta_2 DENS I + \beta_3 AGE + \beta_4 STU + \beta_5 EXP + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (2)$$

where the endogenous variable GHG is the GHG footprint measured in thousands of tons of CO₂ equivalent of each household calculated as equation (1). The variable $RNUTS$ is a categorical variable for the 7 Spanish regions at NUTS 1 level (see Annex 1 for details), $DENS I$ represents the population density, AGE represents the age of the respondents calculated at the time of completion of the household record, STU is a categorical variable that represents the level of complemented studies of the respondents (see Annex 1 for details), EXP is the total amount of the annual expenditure —monetary or non-monetary— of the household, SEX is the binary categorical variable to specify the gender, $YEAR$ is the year of the survey, and finally $AGE * SEX$ captures the interaction effect between the age and the gender.

Besides equation (2), we also present equation (3) — which considers marginal factors— that allows us to capture the percentage effects of gas production with respect to change in our exogenous variables.

$$\ln(GHG) = \beta_1 RNUTS + \beta_2 \ln(DENS I) + \beta_3 AGE + \beta_4 STU + \beta_5 \ln(EXP) + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (3)$$

⁸ Elements of matrix $\mathbf{Q}$ are defined as $g_{ij} = v_{ij}/x_j$, where v_{ij} are the elements of the atmospheric pollutants matrix that describe the total amount of each atmospheric gas, measured in physical units, emitted by each industry. For more details about the environmental extension of the inter-sectorial model see section 4.2 for further details.

Section 4 besides presenting detailed results of the regression analysis it also shows the strategy followed to choose the most appropriate expression for this investigation.

4. Data set and data arrangements

In order to perform our analysis presented in section 3 we built a database including information about the atmospheric pollutant embedded in the consumption basket of women and men, as well as, relevant socio-economic and socio-demographic characteristics of each household. This database combine macroeconomic statistical sources from national accounts —such as input-output tables and environmental accounts— and microeconomic information from household budget surveys. Besides these statistical sources we estimated a so-called bridge matrix that allows us to connect macro and micro data. All in all, we obtain a database for a total of approximately 18,600 one person households of women and men —roughly 3,100 per year under study— the environmental impact of 13 different atmospheric pollutants from their consumption basket of 47 different COICOP products and for 6 years. We consider the case of Spain from 2008 to 2013.

In this section we describe the four statistical data source —i.e. input-output tables (INE, 2018a), environmental accounts (INE, 2018b), household budget survey (INE, 2018c), and bridge matrix— and the arrangements in order to carried out the analysis.

4.1 Input-Output tables

The input-output framework present an exhaustive description of the productive process and the resources-jobs balance of the national economy at a product and sector level mainly measured in monetary units. In the particular case of the Spanish Statistic National Institute, this framework includes a set of yearly supply and use tables (SUT) and input-output tables (IOT) every five years —from 1995 until 2010—. The accounting base changed periodically as a way to update weightings measurements as well as to introduce some methodological variations; the last accounting change was introduced in 2010.

Whereas SUT offers information about all the inputs used by and all the products produced by each industry capturing the fact of joint or multiple-product production, IOT are a simplification of the reality by assuming single-product production. These IOT are the base to compute the Leontief inverse matrix in equation (1). According to this, we estimate a series of yearly —2008, 2009, 2010, 2011, 2012, and 2013— IOT from the SUT following the next procedure. Spanish SUT are of dimension 109 (products) by 64 (industries) for base year 2008 and 64 (products) by 63 (industries) for base year 2010; however, in order to be consistent with other data sources we estimate a 63 by 63 IOT (see Annex 2 for a detailed list).

4.1.a. From SUT to IOT

The SUT have the characteristic of distinguishing between products and sectors in such a way that they are not necessarily the same, which means that one sector or industry can produce more than one product and the secondary production can be clearly identified.

According to EUROSTAT (2008) there are four basic models that allows us to transform SUT to IOT. The most suitable case for our analysis is the so-called product-by-product IOT, whose rows and columns represent homogeneous products and homogeneous units of production, respectively. The product-by-product IOT assumes that each product has being produced in its own specific way, irrespective of the industry or sector where it is produced. In other words, each product has its own typical input structure. For each product the same proportions of products and factor inputs are used to produce one unit of the product disregarding in which industry the product is actually produced. This method could produce some negative values that will require the application of some numerical algorithms to adjust it. One of these methods is the bi-proportional method RAS that will be described later.

We consider a SUT structure as shown in Figure 1, where in the supply table matrix $\mathbf{R}^T$ represents the supply of products in the economy produced by each industry, vector $\mathbf{g}^T$ represents total industries' output, and vector $\mathbf{x}$ total product's output. Moreover, the use table gives information about where the products are used across the different sectors, if as an intermediate consumption ($\mathbf{S}$) or as a final demand component ($\mathbf{Y}$), as well as the values added ($\mathbf{W}$), the industries' output ($\mathbf{g}^T$) and the total product's output ($\mathbf{x}$).

Figure 1: Structure of a supply and use table

<i>Supply table</i>			
	Industries	Supply	
Products	$\mathbf{R}^T$	$\mathbf{x}$	
Output	$\mathbf{g}^T$		
<i>Use table</i>			
	Industries	Final demand	Use
Products	$\mathbf{S}$	$\mathbf{Y}$	$\mathbf{x}$
Value added	$\mathbf{W}$		w
Output	$\mathbf{g}^T$	y	

Source: adapted from EUROSTAT (2008)

Formally, the product-by-product IOT according to the product technology assumption (EUROSTAT, 2008 p. 349) as Figure 2 shows can be calculated following the next mathematical steps (4-10):

Figure 2: Structure of a product-by-product input-output table

<i>Input-output table product by product</i>			
	Products	Final demand	Output
Products	$\mathbf{Z}$	$\mathbf{Y}$	$\mathbf{x}$
Value added	$\mathbf{U}$		w
Input / Output	$\mathbf{x}^T$	y	

Source: adapted from EUROSTAT (2008)

$$\mathbf{T}^a = (\mathbf{R}^T)^{-1} \hat{\mathbf{x}} \quad (4)$$

$$\mathbf{A} = \mathbf{S} \mathbf{T}^a (\hat{\mathbf{x}})^{-1} \quad (5)$$

$$\mathbf{U} = \mathbf{W} (\mathbf{R}^T)^{-1} \quad (6)$$

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{y} \quad (7)$$

$$\mathbf{Z} = \mathbf{S} \mathbf{T}^a \quad (8)$$

$$\mathbf{U} = \mathbf{W} \mathbf{T}^a \quad (9)$$

$$\mathbf{Y} = \mathbf{Y} \quad (10)$$

Finally, it is important to mention that despite the data in SUT is given in purchase and basic prices, the resulting IOT should satisfy the pricing homogeneity assumption by generating all elements of IOT at basic prices (European Commission, 1996; United Nations, 1999).

4.1.b. The RAS method

As it was mentioned before, the above method to estimate a product-by-product IOT can generate some negative values. So, in order to solve this issue the RAS technique —also known as a “biproportional” matrix balancing technique— was implemented (Miller and Blair, 2009, chapt. 7).

The RAS method is used for data reconciliation, making consistency between the entries of some matrix and pre-specified row and columns totals. A mathematical alternative can be the iterative scaling method where a pre-existed matrix is adjusted until its column sum and row sum equals to some pre-specified totals. The method starts multiplying each entry in one row by some factor, this factor is chosen in a way that the sum of all the entries in the row becomes equal to its target where the matrix becomes consistent with all target row totals. Then, the same is performed with the columns, but this last procedure generates inconsistency in the rows again. The rows and columns are adjusted in turns until the algorithm converges to a consistent matrix in both rows and columns totals. This procedure is trying to keep as close as possible to their initial values and avoid losing the essence of the initial matrix.

4.2 Environmental accounts

The environmental accounts are an extension of the IOT, which is consistent with the traditional Leontief model with the aim of dealing the pollution generation in the production processes. Regarding the atmospheric emissions to air, the Spanish Statistic National Institute publishes a series of yearly environmental accounts from 1995 to 2015. The pollutant and sectoral levels of disaggregation vary according to the year base of reference. In relation with our analysis we work with a disaggregation of 63 sectors and for each sector information about 13 different atmospheric pollutants (see Annex 3 for a detailed list). For the purpose of this study and for the sake of clarity in the exposition we only display results for the GHG.

All the atmospheric information is presented in a compatible way with the System of National Accounts measured in physical units —generally tons—, registering the environmental elements desegregate in the different economic activities and household sector as final consumers. The emissions account is elaborated adapting the data to the NACE's classification. The emission accounts follow the same principle of residency as the National Accounts, where the contaminant emissions to the atmosphere are the ones generated by all the activities of the resident units independently of the geographic place where these emissions have really taking place in. It takes record of the gaseous material's flow and residuals particles coming from the national economy. Besides the emissions it does not take into consideration economics agents nor the gases' absorbed by the nature.

One important characteristic of this data set is the fact that the data is delivered by industries, while the estimated IOT is a product-by-product one. Therefore, it is necessary apply a similar methodology described in section 4.1.a to transform atmospheric information from industry to product environmental accounts. In this case, however, we applied the transformation model based on the industry technology assumption of each industry, according to which has its own specific way of produce emissions to the atmosphere irrespective of its product mix (EUROSTAT, 2008, p. 349)⁹. Following the structure of the environmental account according to Figure 3, the next mathematical steps were followed (11-12):

Figure 3: Structure of environmental account

<i>Environmental extension of a supply table</i>		
	Industries	Supply
Products	$\mathbf{R}^T$	$\mathbf{x}$
Output	$\mathbf{g}^T$	
Emissions	$\mathbf{D}$	

<i>Environmental extension of product by product input-output table</i>			
	Products	Final demand	Output
Products	$\mathbf{Z}$	$\mathbf{Y}$	$\mathbf{x}$
Value added	$\mathbf{U}$		w
Input / Output	$\mathbf{x}^T$	y	
Emissions	$\mathbf{V}$		

Source: adapted from EUROSTAT (2008)

$$\mathbf{T}^b = (\hat{\mathbf{g}})^{-1} \mathbf{R} \quad (11)$$

$$\mathbf{V} = \mathbf{D} \mathbf{T}^b \quad (12)$$

The data considered for this study, as it was mentioned before, is between 2008 and 2013 where it was founded in two different year bases. Base 2010 is available from 2010 until 2015 and from the base 2008

⁹ The main reason to apply this strategy was the difficulty to solve the negative values with the RAS technic in this context. Although this approach is not the same as procedure followed for the IOT estimations, it does not get too far from the reality either.

we obtain data for 2008 and 2009. It is really important to take into consideration the difference in the methodology between this two different bases and how it will be fixed in order to work with them jointly.

4.3 Household budget survey

The Spanish household budget survey, published by Spanish Statistic National Institute, provided annually and handing information about the origin and destination of the different consumption's expenditure, as well as some socio-economic and socio-demographic characteristics of the households and member of the consumption unit. This survey has evolved along the years in ways such as the type of population to consider, the size of the sample, the level of disaggregation and even in the periodicity. For our interest we use the household budget surveys with base 2006 which includes microdata from 2008 to 2013.

The consumption's expenditure are the monetary flows that households allocate to the acquisition of some goods and services, as well as the value of the goods received as self-consumption, self-supply, salary in kind, free or reduced meals and imputed rent to the dwelling in which the household resides. The different expenditures are recorded at the time of acquisition, regardless of whether the payment is cash or installment.

The analysis unit in this surveys are the private household residents in main family dwellings and the target population to which the data and tabulations are referred, is the set of private homes as well as the people who are part of them in Spain. The complete size of the sample taken in consideration is approximately 24,000 households per year. However, since we are interesting on the different consumption patterns of women and men only OPH are considered in this study. Just the OPH gives us a total of 3,400 per year roughly —a total of 20,554 households under this study—.

The classification used to collect the households' expenditures is the COICOP, which is structured in 12 large groups and 47 categories (for a detailed information see Annex 4). The disaggregation level varies depending on the grade of geographical disaggregation. For example, at a national level a disaggregation of maximum five digits from COICOP will be reached, while with respect to the autonomous communities it will be four digits. To effect of this study, we will take in consideration a disaggregation level of three digits to a provincial level leaving us with 47 different COICOP categories (see Annex 4).

In contrast to IOT and environmental accounts data, the expenditure on final household consumption is registered at purchase prices, that is, at the price that the buyer actually pays for the products at the time of purchase. Therefore, it will necessary manage this data to transform all the households' expenditure to basic prices that will be explained later.

We will find three types of files: household file, member file, and expenditure file. The household file recollects data of the households' characteristics as the size and composition of the household and other general information of the residential area —as from example autonomous community, size of the municipality, population density, etc.—. The member file shows information about all the people who are members of collaborating homes. It is possible to find information such as nationality, study level, work situation, etc. Finally, the expenditure file, as it was mentioned before, captures the households' expenditure of the different families. This file gives us the quantity, percentage and has in a differentiate way monetary expenditure, no monetary expenditure, self-consumption, self-supply, rent, etc.

4.4 Bridge matrix

After handling all the aforementioned data, we continue with the creation of the so-called bridge matrix. This is a matrix that relates 47 COICOP products with 63 NACE products and it is essential to consolidate our macroeconomic data —such as IOT and their respective environmental accounts—and our microeconomic data about the expenditure on the consumption basket of each household we obtain from the household budget surveys. Moreover, this bridge matrix should allow for transforming expenditures of private consumption on purchase prices into basic prices.

Given the lack of publicity on this subject from the Spanish Statistic National Institute, on the bases of the bridge matrix used in Serrano (2005) we built our own series of bridge matrices for our six years of interest —from 2008 to 2013— under certain assumptions. It was necessary to apply the RAS method explained above.

The main assumption behind this method is that the proportion against the totals of each expense has remained constant over the years. This implies that there have not been great technological changes along time. It is known that technologies have been growing exponentially in recent years, many times more than expected. This is why one of the challenges for the future would be to develop an appropriate bridge matrix for each year, taking into account the changes in both consumption patterns and technology that the society have been confronting recently.

5. Results and discussion

This section explores total emissions generated between 2008 and 2013 by Spanish households, aiming at studying the differences in the environmental impact of the consumption patterns between women and men. We considered only households with one member —the so-called OPH—. The work done allows us to analyze these effects with respect to 13 different types of atmospheric pollutants; however, for presentation purposes in this section we focus only on total GHG measured in thousands of tons of equivalent CO₂. This section is divided into three subsections: first, the data is summarized in a general way in order to contextualize the information; second, an analysis of average total GHG emissions by gender and COICOP, considering the structure of age and quintiles of expenditure level; and third, in order to obtain a more consistent answer to the question of this study, the econometric results are shown.

5.1 Simple descriptive statistics

In this section a simple descriptive statistics of the data is presented, paying special attention to age structure and quintiles of expenditure level. It is important to remember that Spanish household budget surveys can be extrapolated for the entire Spanish population. So, Table 1 presents the information of the sample, whereas Table 2 presents of the population.

**Table 1: General structure of the number of one-person households (OPH) by sex.
Spain 2008-2013 – Sample**

	2008	2009	2010	2011	2012	2013
Total households	22,077	22,346	22,203	21,680	21,808	22,057
Total OPH	3,186	3,333	3,382	3,445	3,510	3,698
Women OPH	2,009	2,032	2,049	2,079	2,098	2,213
Men OPH	1,177	1,301	1,333	1,366	1,412	1,485
Average age OPH	61	60	60	61	60	60
Average spending OPH	17,845	17,992	17,592	17,872	17,579	17,190

**Table 2: General structure of the number of one-person households (OPH) by sex.
Spain 2008-2013 – Population**

	2008	2009	2010	2011	2012	2013
Total households	17,067,747.5	17,384,274	17,644,384.18	17,897,736.92	18,091,837.83	18,212,213.87
Total OPH	3,796,126	3,907,359	4,013,530	4,118,003	4,263,015	4,410,478
Women OPH	2,141,463	2,114,542	2,166,869	2,238,146	2,258,126	2,368,004
Men OPH	1,654,662	1,792,817	1,846,661	1,879,858	2,004,889	2,042,475
Average age OPH	58	57	57	57	57	57
Average spending OPH	18,503	18,437	17,758	18,239	17,960	17,325

We see that total OPH have been increasing over the period 2008-2013, representing the 14% – 17% of the total sample and the 22% – 24% of the total population. Between the years of interest, the OPH of women are ranged from 52% to 56% of the total OPH, which means that more women live alone in Spain than men. The average age of this data are 60-61 years old for the sample and 57-58 years old for the population. As these tables show, the average expenditure of this kind of households is around 17,100 euros and 18,000 euros per year in the case of the sample, whereas in the case of the total population the average expenditure varies range 17,300 euros and 18,500 euros per year. We observe that not necessarily these average expenses are growing over the years.

Tables 3 and 4 present the age structure of OPH according to gender at the population level (see Tables A1 and A2 of Annex 5 for results at sample level). We observe that the average age for women slightly varies around 62 years old, while in men it varies between 50 and 51 years old, approximately 10 years of difference. At the time of analysis, only 44% —on average— of women who lived alone are younger than 65 years old. On the other hand, those over 65 years old are the ones who most frequently live alone with high difference in the case of women. This tendency reversed in the case of men, for whom the 68% on average of OPH have less than 65 years old. From here it is possible to conclude that the reason behind this fact is that women live longer than men¹⁰ and it is justified by the average age of this kind of

¹⁰ See www.weforum.org

households.

**Table 3: Structure of one-person households (OPH) of women by age.
Spain 2008-2013 – Population**

	2008	2009	2010	2011	2012	2013
Average age OPH	62.782	62.332	62.324	62.83	62.582	62.75
≤30	154,713	124,573	138,358	160,512	133,385	132,274
30<;≤45	305,185	341,252	357,188	338,576	389,320	417,469
45<;≤65	442,100	458,916	457,926	508,419	489,565	505,841
<65	1,239,466	1,189,802	1,213,397	1,230,640	1,245,856	1,312,420

**Table 4: Structure of one-person households (OPH) of men by age.
Spain 2008-2013 – Population**

	2008	2009	2010	2011	2012	2013
Average age OPH	51.177	50.76	50.938	50.808	50.867	50.581
≤30	158,399	211,905	162,983	200,555	239,333	214,130
30<;≤45	616,665	619,308	679,689	637,821	676,710	751,123
45<;≤65	437,972	507,138	546,118	587,429	614,873	599,977
<65	441,627	454,466	457,871	454,053	473,973	477,245

Analyzing at the expense levels, Tables 5 and 6 present the data according to quintiles at the population level (see Tables A3 and A4 of Annex 5 for results at sample level), where Q₁ is the average of the 20% of household with more expenses, Q₂ the second with more expenses and so on for the rest of the quintiles. It is noticeable that men have higher expenses in average that women in practically all the cases, which could be due to salary and pension differences between men and women (de la Rica, Dolado and Llorens, 2005). The annual average expenditure of women ranges between 17,200 and 17,800 euros per year while men have an annual average expenditure between 18,000 and 19,610 euros.

**Table 5: Structure of one-person households (OPH) of women by quintile of expenditure.
Spain 2008-2013 – Population**

	2008	2009	2010	2011	2012	2013
Average spending OPH	17,796	17,443	17,472	17,420	17,878	17,220
Q ₁ (higher quintile)	35,806	34,522	34,305	33,083	34,012	31,771
Q ₂	19,183	19,523	19,584	19,621	19,334	19,557
Q ₃	14,157	14,792	14,754	14,709	14,974	14,839
Q ₄	10,959	11,150	11,145	11,233	11,697	11,658
Q ₅ (lowest quintile)	7,083	7,274	7,696	7,626	7,951	7,793

Table 6: Structure of one-person households (OPH) men by quintile of expenditure. Spain 2008-2013 – Population

	2008	2009	2010	2011	2012	2013
Average spending OPH	19,417	19,609	18,095	19,215	18,052	17,447
Q ₁ (higher quintile)	37,346	38,995	34,311	37,853	33,761	32,047
Q ₂	21,828	21,100	21,157	21,337	20,393	20,002
Q ₃	16,259	15,984	15,427	16,147	15,684	15,517
Q ₄	12,072	11,700	11,630	12,062	11,685	11,506
Q ₅ (lowest quintile)	7,702	7,639	7,618	7,485	7,415	7,260

5.2 Greenhouse gases embedded consumption baskets

In this section we analyze total GHG on average embedded in consumption baskets of OPH of women and men taking in account different age range and different levels of consumption divided by quintiles. Finally we also analyze average total GHG by COICOP classification to see difference in the consumption patterns.

Tables 7 and 8 present the yearly structural analysis of GHG emissions by age and Tables 9 and 10 by quintiles, both at the population level (see Tables A5, A6, A7 and A8 of Annex 5 for results at sample level).

Table 7: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women by age. Spain 2008-2013 – Population

	2008	2009	2010	2011	2012	2013
≤30	7,913	5,572	5,098	4,328	4,280	4,093
30<≤45	7,869	6,747	5,666	5,478	5,062	4,537
45<≤65	7,849	6,836	5,753	5,606	5,775	4,950
<65	5,526	5,250	4,350	4,561	4,824	4,324

Table 8: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of men by age. Spain 2008-2013 – Population

	2008	2009	2010	2011	2012	2013
≤30	7,494	6,056	5,081	4,757	4,266	3,919
30<≤45	7,927	7,110	5,186	5,506	5,325	4,805
45<≤65	7,772	7,498	5,430	6,034	5,488	4,743
<65	5,462	5,207	4,342	4,884	4,752	4,218

It is hard to find patterns, but one thing that can be concluded is that, as the years go by, GHG emissions decrease on average. On average and in most cases, women contribute less than men both by age and quintiles. It is possible to find differences between different age ranges. On average “young” people (less than or equal to 30 years old) contribute with more greenhouse gases than “old” people (more than 65 years old) for both, women and men. This may be due to the low purchasing power at the time of retirement.

As expected, the richest quintiles contribute to GHG emissions more than the poorest and the richest quintiles of men contribute substantially more than the richest quintiles of women.

Table 9: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women by quintile of expenditure. Spain 2008-2013 – Population

	2008	2009	2010	2011	2012	2013
Q ₁ (higher quintile)	12,812	9,913	11,130	8,478	9,415	8,006
Q ₂	6,704	7,082	5,805	5,793	5,243	4,944
Q ₃	5,606	5,367	3,659	4,148	4,776	4,081
Q ₄	4,580	4,269	2,633	3,780	3,614	3,428
Q ₅ (lowest quintile)	2,858	2,644	1,331	2,402	2,146	1,953

Table 10: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of men by quintile of expenditure. Spain 2008-2013 – Population

	2008	2009	2010	2011	2012	2013
Q ₁ (highest quintile)	16,399	15,191	15,472	12,013	10,386	8,958
Q ₂	8,562	7,354	4,893	5,963	6,029	5,333
Q ₃	5,616	5,043	2,738	4,653	4,008	3,636
Q ₄	3,216	3,333	1,413	2,709	2,882	2,936
Q ₅ (lowest quintile)	2,141	2,143	683	1,867	2,259	1,920

Figures 1 and 2 display the GHG emissions embedded on average by COICOP classification. As a simplification we show the 12 COICOP categories, showing the differences of consumption patterns by gender in 2008 and 2013 (see Tables A9 and A10 of Annex 5 for results of other years).

Figure 1: Greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women and men by COICOP groups. Spain 2008 – Population

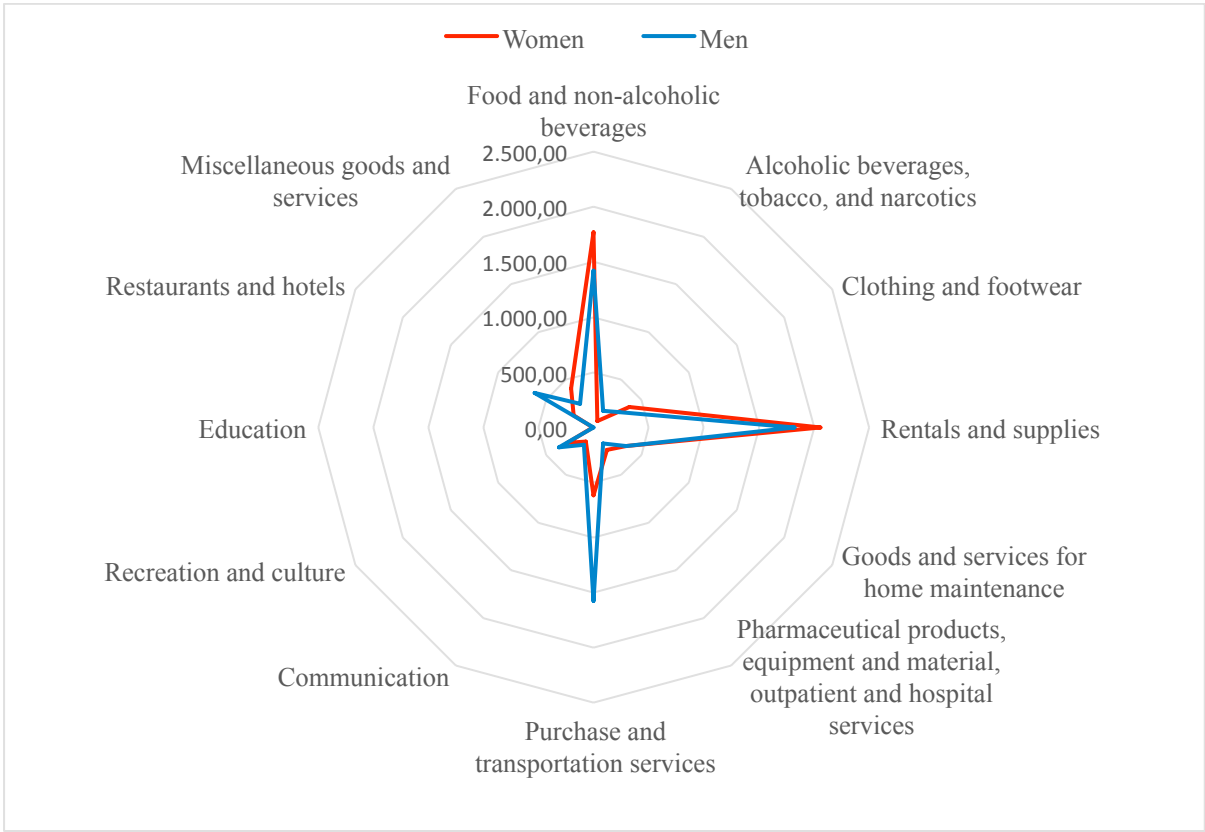
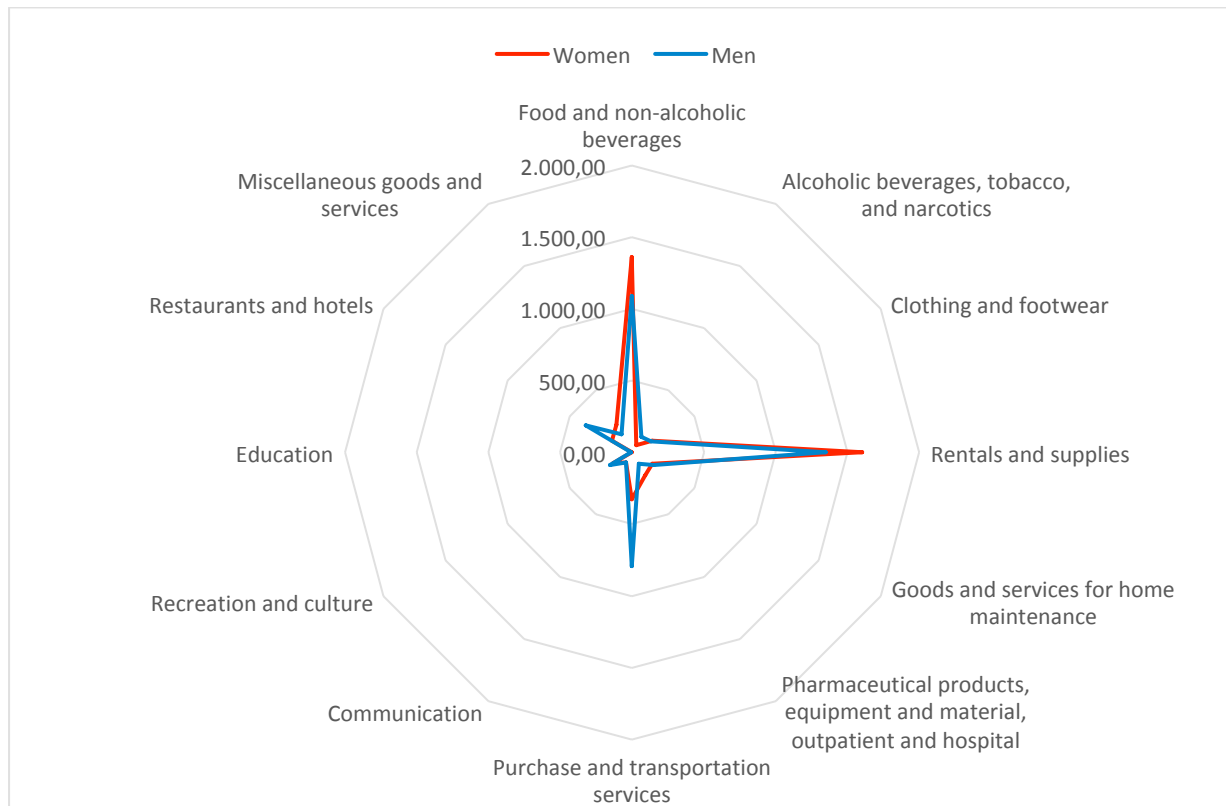


Figure 2: Greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women and men by COICOP groups. Spain 2013 – Population



It is possible to observe that patterns between these years are very similar, but different in scale. We observe that even though women contribute more in more categories than men, men contribute more on the total average. In categories such as “Purchase and transportation services” men lead in production of GHG as opposed to women. This is because men tend to buy and use more private transportation, this being one of the main sources for the production of greenhouse gases. It is interesting to analyze how the average of our sample is quite high, both for the sample and for the population. We see how we find a higher percentage of women and how, on average, they produce less gas than men.

5.3 Econometric Results

In this section we analyze the different econometrics models proposed in the methodology (see section 3). Our aim is to study the role of our variable of interest, gender. Both lineal and logarithmic models are included with WLS regressions; in order to summarize the results, the most relevant equations are presented. First of all, the equations that include all the variables of interest with and without logarithms are analyzed; then, following the best Akaike Information Criteria (AIC) we select the most appropriate model to continue the analysis with more detail. Figure 3 presents results of the regression given by the equation (2):

$$GHG = \beta_1 RNUTS + \beta_2 DENSI + \beta_3 AGE + \beta_4 STU + \beta_5 EXP + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (2)$$

Figure 3: Weight least square regression of equation (2)

Coefficients:					
	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	7.201e+05	1.649e+04	43.662	< 2e-16	***
RNUTS1	4.009e+02	5.532e+01	7.246	4.45e-13	***
RNUTS2	1.425e+02	5.192e+01	2.744	0.006078	**
RNUTS4	4.544e+02	5.513e+01	8.243	< 2e-16	***
RNUTS5	1.443e+02	5.343e+01	2.701	0.006928	**
RNUTS6	2.104e+02	5.488e+01	3.833	0.000127	***
RNUTS7	-3.951e+01	7.044e+01	-0.561	0.574881	
DENSI	2.338e+02	1.701e+01	13.746	< 2e-16	***
AGE	-1.759e+00	1.475e+00	-1.192	0.233098	
STU1	2.043e+01	8.061e+01	0.253	0.799953	
STU2	9.414e+01	5.486e+01	1.716	0.086210	.
STU3	1.049e+02	5.091e+01	2.061	0.039355	*
EXP	2.813e-01	6.115e-03	46.005	< 2e-16	***
SEX	2.349e+02	1.001e+02	2.347	0.018916	*
YEAR	-3.583e+02	8.203e+00	-43.677	< 2e-16	***
AGE:SEX	-4.435e+00	1.604e+00	-2.765	0.005699	**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

The above equation is lineal and uses all the variables of interest. It is possible to observe that the variables that refer to the *RNUTS*, which represent the seven Spanish regions at the NUTS I level (see Annex 1 for a detailed list) have positive parameters and significant between the 0.001 and 0.01 (except Region 7, Canary Islands), being the Madrid Community (Region 3) the category of reference. The parameter of population density (*DENSI*) is positive and significant at 0.001, which means that if the population density increases in one unit the total GHG will increase in 0.0233 thousands of tons of equivalent CO₂ (23.3 thousands of kilograms). The parameter of *AGE* variable is not significant; the same as with *STU1*, which is the variable that represents people without studies or with first grade studies as opposed to those with high level of studies. The parameters of the variables that represent the secondary education first and second cycle are significant at 0.1 and 0.05, respectively. Both parameters are positive, which means that the parameter of secondary education affects in a positive way the production of GHG compared to the class of highly educated people. As it is expected the parameter of the variable that represents the household expenditure (*EXP*) is positive and significant at 0.001, as well as the parameter of our variable of interest *SEX* is positive and significant at 0.05, allowing us to infer that the consumption budget of men generate more GHG emissions than women. It is also interesting to analyze the variable *YEARS*, whose parameter is negative and significant at 0.001; in other words, as the years go by, our society, or at least the Spanish OPH, produce less and less GHG emissions. This may be due to the technological advances being more ecofriendly and also to environmental policies. The parameter of the variable *AGE*SEX* is also negative and significant, which means that there is an interaction effect and so, that the impact of age on the dependent variable differs with respect to gender. In this case, as the parameter is negative —and considering that *SEX* denotes men by one—, we conclude that each additional year in men has a significantly lower effect than each additional year in women. *Ceteris paribus*,

we will see a different slope (first derivate) in magnitude for men than for women, when we consider the impact of age on GHG emissions.

Since we are also interested in analyze the logarithmic function to see the marginal effect of the variables, Figure 4 shows the results of the equation (3):

$$\ln(GHG) = \beta_1 RNUTS + \beta_2 \ln(DENSI) + \beta_3 AGE + \beta_4 STU + \beta_5 \ln(EXP) + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (3)$$

Figure 4: Weight least square regression of equation (3)

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	1.262e+02	2.337e+00	54.017	< 2e-16 ***
RNUTS1	5.697e-02	8.142e-03	6.997	2.69e-12 ***
RNUTS2	1.289e-02	7.125e-03	1.809	0.070474 .
RNUTS4	8.603e-02	8.264e-03	10.411	< 2e-16 ***
RNUTS5	7.654e-03	7.354e-03	1.041	0.297989
RNUTS6	3.114e-02	8.120e-03	3.835	0.000126 ***
RNUTS7	-1.366e-02	1.188e-02	-1.150	0.250313
LDENSI	7.087e-02	4.697e-03	15.088	< 2e-16 ***
AGE	3.278e-04	1.867e-04	1.756	0.079103 .
STU1	2.743e-02	7.289e-03	3.763	0.000168 ***
STU2	2.534e-02	5.923e-03	4.279	1.89e-05 ***
STU3	1.773e-02	6.658e-03	2.663	0.007750 **
LEXP	9.986e-01	5.436e-03	183.704	< 2e-16 ***
SEX	3.307e-02	1.467e-02	2.254	0.024219 *
YEAR	-6.343e-02	1.161e-03	-54.629	< 2e-16 ***
AGE:SEX	-9.735e-04	2.460e-04	-3.958	7.59e-05 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Similarly to the previous results, the parameters of the regional variables are positive and significant, except for Region 5—which includes the autonomous communities of Catalonia, Valencia and Balearic Island—and again Region 7 (Canary Island). These results mean that regions with a significant positive coefficients contribute more in percentage to the production of GHG than the reference region that has been set to Madrid (Region 3). The parameter of the logarithm of population density is positive and significant at 0.001, meaning that it will be a 0.07% increment in the production of gases if the population density increases in 1%. For this model the parameter of the variable age (*AGE*) is positive and significant at 0.1, so as we get older we contribute more percentage-wise to the production of GHG. All the parameters of the variables for the education level are positive and significant over the higher education level, in other words, people with or without secondary studies contribute more in percentage at the production of GHG that the people with higher education level. The parameter of the variable logarithmic of expenditure is positive and significant at 0.001, which means that gases will increase a 0.0998% if the household's expenditure increase in 1%. The parameter of the variable of interest *SEX* is now more positive, with a significant level of 0.05, which indicates that men increase more the percentage of gas production compared to women, specifically 0.03% more. Lastly, the parameters of years and *AGE*SEX* are negative and significant, so the interpretation is the same as before.

This last model is the one that gives us the lowest AIC (4354.8), but given the high correlation between the educational level and the expenses, we preferred to leave education level variable outside, leaving us with the equation (13) for the logarithmic case, this being the with second best AIC of 4381.217. Figure 5 presents the results.

$$\ln(GHG) = \beta_1 RNUTS + \beta_2 \ln(DENSI) + \beta_3 AGE + \beta_5 \ln(EXP) + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (13)$$

Figure 5: Weight least square regression of equation (13)

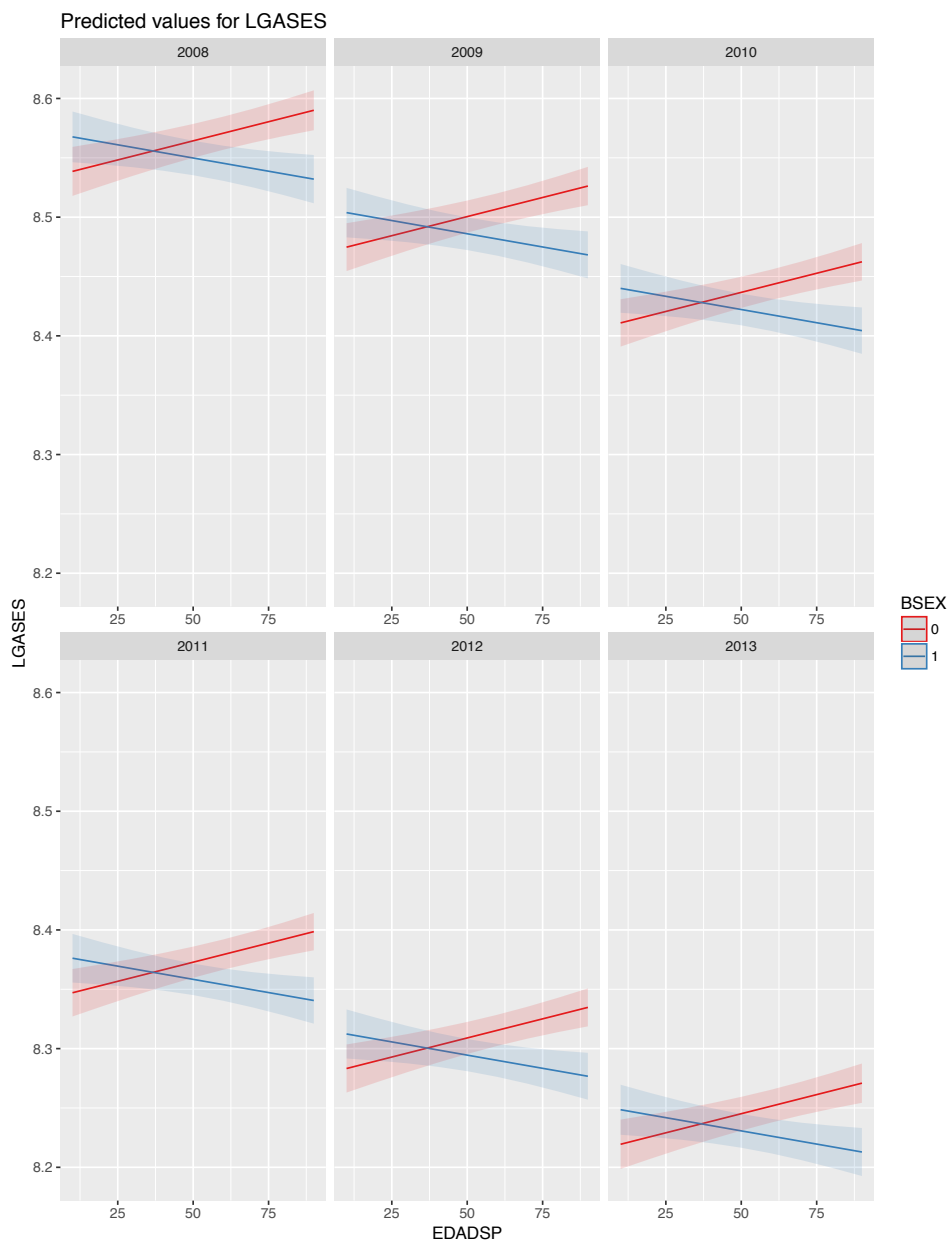
Coefficients:					
	Estimate	Std. Error	t value	Pr(> t)	
(Intercept)	1.271e+02	2.288e+00	55.555	< 2e-16	***
RNUTS1	5.757e-02	8.152e-03	7.062	1.69e-12	***
RNUTS2	1.335e-02	7.134e-03	1.871	0.06139	.
RNUTS4	8.615e-02	8.278e-03	10.407	< 2e-16	***
RNUTS5	8.613e-03	7.371e-03	1.169	0.24261	
RNUTS6	3.181e-02	8.123e-03	3.916	9.04e-05	***
RNUTS7	-1.313e-02	1.191e-02	-1.103	0.27023	
LDENSI	7.379e-02	4.611e-03	16.001	< 2e-16	***
AGE	6.437e-04	1.568e-04	4.105	4.06e-05	***
LEXP	9.926e-01	5.005e-03	198.341	< 2e-16	***
SEX	3.998e-02	1.454e-02	2.751	0.00595	**
YEAR	-6.383e-02	1.138e-03	-56.084	< 2e-16	***
AGE:SEX	-1.089e-03	2.435e-04	-4.473	7.76e-06	***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

In this case the parameters of the regional variables are positive and significant, without considering Regions 5 and 7. The parameter of the logarithm of density is positive and significant at 0.001, therefore it is possible to conclude the same interpretation as above. For the parameters of the variables *AGE* and logarithm of expenditure are also understood in the same way that the last model. Now, focusing in our variable *SEX*, it is significant with lower *p* value than before at 0.01 and positive, concluding again that men produce more GHG than women, specifically a 0.3998% more. The parameter of the variable *YEAR* and *AGE*SEX* continue with the same interpretation.

Figure 6 presents graphs related to equation (13) in order to better understand the situation of Spain and the gender differences regarding the GHG emissions embedded in private consumption. Over the years, the percentage of GHG emissions has been decreasing. It is also interesting to notice that women younger than 50 years old tend to be less polluting than men, to then revert the interpretation leaving women above men. Moreover, the slope of the percentage emissions of women is more pronounced than men, that their changes in GHG emissions are more constant than women. This can be seen in the aforementioned studies (Croson and Gneezy, 2009), where women are more sensitive than men according to the scenario; for this case, the woman's age produces a change in her behavior in a stronger way than in the case of men.

Figure 6: Graphs from equation (13). Spain, 2008-2013

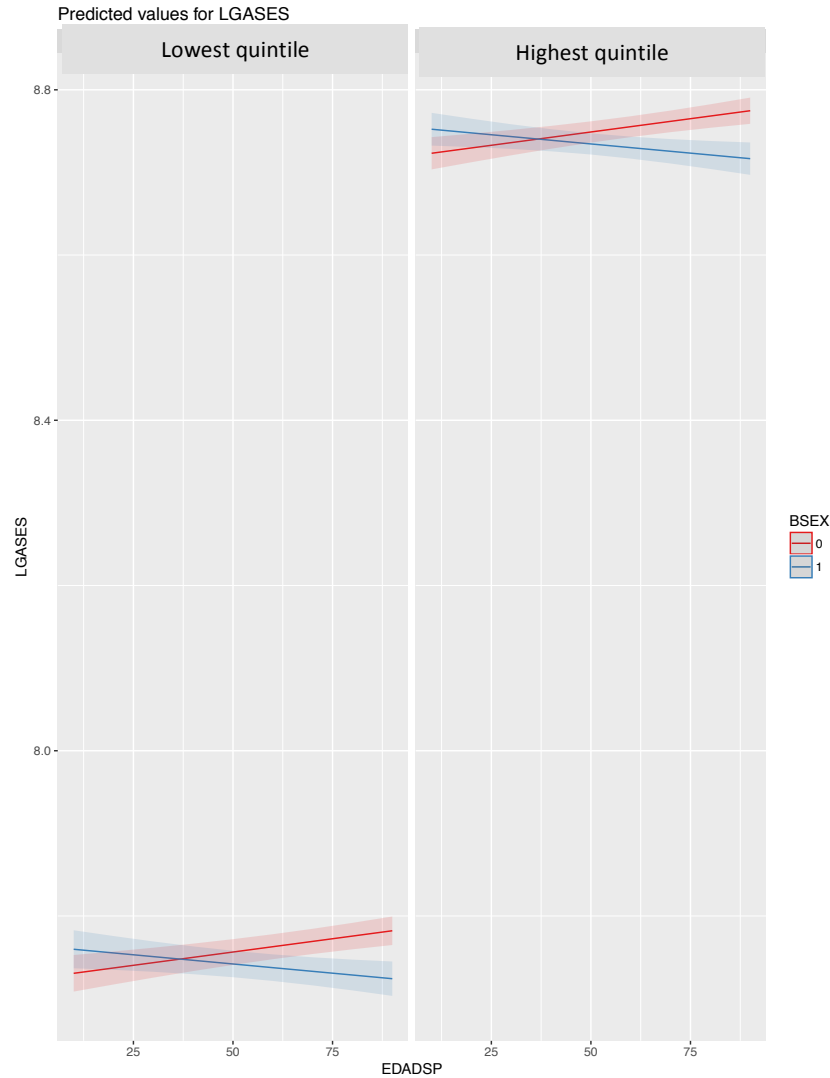


One of the main determinants of the GHG emissions is the climate, for this reason Figure 7 presents results of equation (13) of three regions that might represent three different climate in Spain: Region 1 (Northwest) —which includes Galicia, Principality of Asturias and Cantabria—; Region 3 (Madrid) —Community of Madrid—; and Region 5 (East) —including Catalonia, Valencian Community and Balearic Islands—. The Northwest region is the one that contributes the most compared to the Center and East regions in the percentage production of GHG. The Center and East regions are more similar in the percentage emissions of GHG. Figure 8 shows the graph of the equation (13) but distinguishing the lowest and the highest quintile. There is a great difference between the richest and the poorest, contributing substantially more in the emissions of GHG the rich than the poor.

Figure 7: Graphs from equation (13) and for Regions 1, 3 and 5. Spain, 2008-2013



Figure 8: Graphs from equation (13), for Regions 1, 3 and 5 and for highest and lowest quintile. Spain, 2008-2013



5.3.a. An extension of the analysis

Finally, considering the direct relation between the endogenous variable GHG with the exogenous variable EXP we decided to remove expenditure logarithm variable as it can be seen in equation (14); results are presented in Figure 9:

$$\ln(GHG) = \beta_1 RNUTS + \beta_2 \ln(DENSI) + \beta_3 AGE + \beta_6 SEX + \beta_7 YEAR + \beta_8 AGE * SEX + \varepsilon \quad (14)$$

Figure 9: Weight least square regression of equation (14)

```

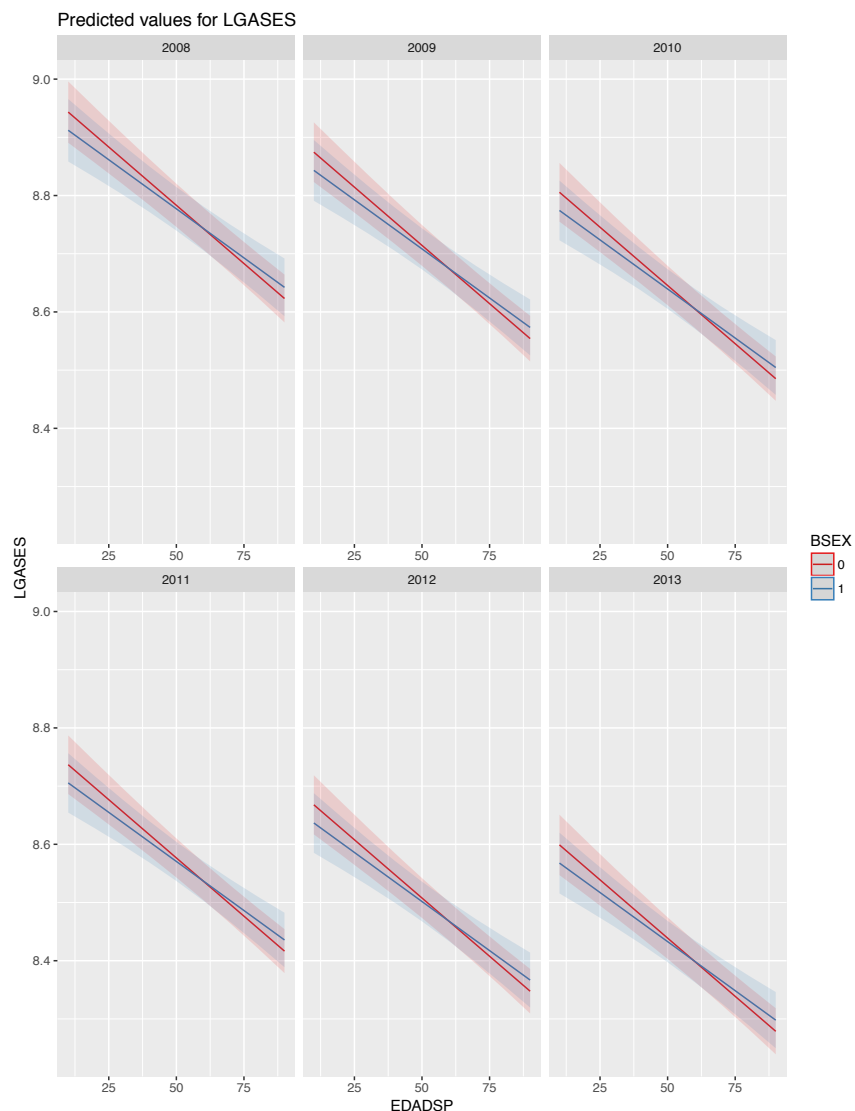
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.473e+02  5.757e+00  25.584 < 2e-16 ***
RNUTS1      -1.777e-01  2.009e-02  -8.845 < 2e-16 ***
RNUTS2      -5.989e-02  1.810e-02  -3.308 0.000942 ***
RNUTS4      -2.092e-01  2.029e-02 -10.308 < 2e-16 ***
RNUTS5      -1.305e-01  1.866e-02  -6.990 2.83e-12 ***
RNUTS6      -2.434e-01  2.105e-02 -11.566 < 2e-16 ***
RNUTS7      -3.755e-01  2.728e-02 -13.766 < 2e-16 ***
LDENSI      -4.607e-02  1.094e-02  -4.211 2.55e-05 ***
AGE         -4.003e-03  3.723e-04 -10.752 < 2e-16 ***
SEX         -3.754e-02  3.594e-02  -1.045 0.296193
YEAR        -6.887e-02  2.863e-03 -24.054 < 2e-16 ***
AGE:SEX      6.301e-04  5.834e-04   1.080 0.280125
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Under this situation results are completely different. We find a negative parameter and a significance in practically all the parameters, except in the parameters of *SEX* and *AGE*SEX*. In this model, the gender has nothing to contribute in the emissions of GHG. In this case, the variables that represent the Spanish regions are found to contribute between 0.0598% and 0.355% less than the Community of Madrid. The density is interpreted as follows: an increase of 1% in the population density produce a 0.046% less of GHG. Regarding age, we conclude that as we get older we behave more ecofriendly. The variable year maintains its interpretation, but now the *AGE*SEX* interaction coefficient is positive, which means that the slope for men is smoothed as age increase compared to women, when we compare GHG emissions with respect to age.

Figure 10 presents the result taking in consideration the equation (14). In this case, before the age of 50 years old —approximately— women are more polluting than men and the roles are reversed later. It is also shown that, over the year the percentage emissions of GHG is decreasing and again we can see how the slope of women is more pronounced than men, certifying that women are more sensitive to changes.

Figure 10: Graphs from equation (14). Spain, 2008-2013



To summarize, we found that when analyzing the emissions of GHG in Spanish OPH between 2008 and 2013, many household's characteristic variables take a role. In the case of the region, we see that in comparison to the Community of Madrid, all other regions contribute more —except for Regions 5 and 7—, the reason of such behavior would need a further analysis of the data. In some cases we see how the lower the educational level, the less ecofriendly will be their consumption behavior. The density of the population is also an important variable, since it summarizes that the more agglomerations —when expenditure is considered—, the more polluting the population becomes. In most cases, it is shown that as we grow older our consumption patterns are contributing to more GHG. Besides, it is encouraging to see how, over the years, society produce less GHG, which may be due to more environmentally friendly technologies such as public policy legislation on these issues in the European Union. Finally, we see how the representative variable of the gender appears to have a significant impact, and even more interestingly, how women have consumption patterns more ecofriendly than men —consciously or unconsciously— but

this result totally changes when we do not control for the total expenditure. In that case, if expenditure was the same, men seem to be less pollutant than women with the same characteristics.

6. Conclusions

In this study we aimed at answering a particular question: Is the environmental impact of private consumption of women and men different? If so, what are the main variables that might explain these differences? And in particular, what is the role played by gender? We analyzed the case of Spain during a six-year period —from 2008 to 2013— for 13 different atmospheric pollutants and 47 COICOP products —grouped in 12 main categories—.

To answer these questions first, we calculated the total atmospheric pollutants embedded in the consumption patterns of OPH of women and men by the application of an environmental extended input-output model; and then, we implemented an econometric model considering WLS regression. To this aim, we built a specific database from three statistical sources provided by the Spanish Statistic National Institute —input-output tables and environmental accounts from the Spanish National Accounts, and the microdata from the Spanish household budget survey—, and the estimation of a bridge matrix that allowed the consolidation of macroeconomic dataset with microeconomic information. For presentation purposes, this paper only shows results for an aggregation of the 6 GHG.

From the results of the analysis, we conclude that when it is looking at emissions of GHG embedded in the consumption baskets of OPH gender differences take a relevant position. On the one hand, there are significant differences in consumption patterns; so that, although women's private consumption has a higher GHG footprint in most of the 12 COICOP categories —such as, “Food and non-alcoholic beverages”, “Clothing and footwear”, “Rentals and supplies”, etc.—, men's total GHG footprint is higher. The greatest difference occurs in "Purchase and transportation services" category, which includes products as “Purchase of vehicles”, “Use of personal vehicles”, and “Transport services”, being the “Use of personal vehicles” the one that contributes the most to the GHG emissions.

On the other hand, the parameter of the representative variable of sex is positive and significant, that means men's consumption basket contributes more to GHG emissions both directly and percentage than women's one. It is also interesting to analyze the variable that captures the interaction between age and sex. A negative and significant parameter is appreciated; this represents that there is an effect between the interactions of these two variables. In this case, we conclude that each additional year in men has a significantly lower effect than each additional year in women, therefore there might be different behaviors between them according to age. In fact, it is possible to appreciate how the patterns between men and women change around 50 years old; it allows us to conclude that men contribute more to GHG emissions than women while they are young, while after 50 years women contribute more. A deeper analysis of the composition of the consumption baskets by age and gender would allow us to conclude more about the reasons of this change of behavior. A preliminary hypothesis would be that older women take more care about their health than older men.

Given that we are facing a high level of correlation between our endogenous variable —total GHG embedded in private consumption— and our exogenous variable —expenditure—, the results were

observed without this variable. The regression showed completely different results. Since the variable sex captures part of the level of income, the analysis concludes that it is women who contribute the most in GHG emissions. The same happens with practically all the rest of the variables, which give completely different conclusions to the models created that include the level of OPH expenditures.

All in all, these results are important in terms of policy implications, since the design of effective environmental policies aimed at modifying particular non-ecofriendly consumption behaviors, should take into account the composition consumption baskets —i.e. the consumption patterns— to study the environmental impacts of private consumption of different population groups, particularly by gender.

It is important to note that this type of analysis is only the beginning of many of the possibilities that the database built might allow us to work with. For instance, also econometric analysis could be achieved deeper at regional level —and at level of autonomous communities—, differentiating the urban and rural emplacement of the household, or considering the level of studies. Besides, this kind of analysis has the potential to be extended at international level by including other states members of the European Union.

Moreover, extending our database to a large time period we also find an extensive range of possibilities regarding future studies. In this case, a longitudinal analysis might be done by observing the changes over the years in the consumption patterns of both men and women and derivatives of socio-economic changes such as the increase in the rate of activity and female employment or the effect of economic crises and determine their effect on the emission of polluting gases.

Another interesting extension of our analysis would be to cover other atmospheric pollutant that we already have in our database. In this case, the different implications of environmental policies would be relevant. Whereas the emissions of GHG are responsible of a global environmental problem that affect all the world —the global warming—, the emissions of the so-called local or regional gases are responsible for the displacement of environmental problems to other territories with important effects, among others, on the population health. The environmental policies designed for both cases should be different.

Finally, a natural way of improvement and extension of this study is the solution of the limitations of the current analysis. The most important one is the estimation of a time series of the so-called bridge matrix. Due to the lack of Spanish public information about this matrix and the little information that we have regarding the evolution of technical changes in the correspondence between COICOP and CPA products, we built our bridge matrix series under some assumptions that need to be relaxed in the future. This would be by far the most important challenge in the future of this research.

In conclusion, the results of this work might be an important contribution to the existing literature on the topic of environmental impacts and gender. And it might open a door to a wide variety of research not only at gender levels, but much more.

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Annex 1: Description of variables in the econometric analysis

Variable	Description	Observation
GHG	Total of Greenhouse Gases embedded in consumption basket	Numerical
RNUTS	Region (NUTS I) / Autonomous communities (NUTS II) 1 – Northwest: Galicia, Principality of Asturias, Cantabria 2 – Northeast: Basque Country, Navarre, La Rioja, Aragon 3 - Madrid Community: Madrid 4 – Center: Castile-Leon, Castile-La Mancha, Extremadura 5 – East: Catalonia, Valencian Community, Balearic Islands 6 – South: Andalusia, Region of Murcia, Ceuta, Melilla 7 – Canarias: Canary Islands	Categorical Categorical Categorical Categorical: Reference Categorical Categorical Categorical Categorical
DENSI	Population Density	Numerical
AGE	Respondent's age	Numerical
STU	Completed studies reduced 1 - Without studies or with first grade studies 2 - Secondary education first cycle 3 - Secondary education second cycle 4 - Higher education	Categorical Categorical Categorical Categorical Categorical: Reference
EXP	Total amount of the annual expenditure of the monetary and non-monetary household	Numerical
SEX	Respondent's sex 0 - Women 1 - Men	Categorical Categorical: Reference Categorical
YEAR	Year of the survey: 2008, 2009, 2010, 2011, 2012, 2013	Numerical

Annex 2: List of 63 NACE sectors

1	Products of agriculture, livestock and hunting, and related services
2	Products of forestry and logging, and related services
3	Fish and other fishery products; aquaculture products; fishing support services
4	Extractive industries
5	Food products; drinks; manufactured tobacco
6	Textile products; clothing; leather goods and footwear
7	Wood and cork and products made of wood and cork, except furniture; basketry and plaiting articles
8	Paper and paper products
9	Print and reproduction services of recorded media
10	Coke and petroleum refining products
11	Chemical products
12	Basic pharmaceutical products and their preparations
13	Rubber and plastic products
14	Other non-metallic mineral products
15	Metallurgy products and metal products
16	Metal products, except machinery and equipment
17	Computer, electronic and optical products
18	Electric equipment
19	Machinery and equipment n.c.o.p.
20	Motor vehicles, trailers and semi-trailers
21	Other transport material
22	Furniture; Other manufactured products
23	Repair and installation services of machinery and equipment
24	Electric power, gas, steam and air conditioning
25	Natural water; water treatment and distribution services

26	Sewer services; waste collection, treatment and disposal services; utilization services; sanitation services and other waste management services
27	Constructions and construction works
28	Wholesale and retail trade services and repair services of motor vehicles and motorcycles
29	Wholesale trade and business intermediation services, except of motor vehicles, motorcycles and mopeds
30	Retail trade services, except of motor vehicles and motorcycles
31	Land transport services, including pipelines
32	Maritime and inland waterway transport services
33	Air transport services
34	Storage services and transport auxiliaries
35	Postal and courier services
36	Accommodation and food and beverage services
37	Editing services
38	Cinematographic, video and television services; sound recording and music editing; radio and television programming and broadcasting services
39	Telecommunications services
40	Programming, consulting and other services related to computer science; Information services
41	Financial services, except insurance and pension funds
42	Insurance, reinsurance and pension insurance services, except compulsory social security
43	Services auxiliary to financial services and insurance services
44	Real estate services
45	Legal and accounting services; business headquarters services; business management consulting services
46	Architectural and engineering technical services; technical testing and analysis services
47	Research and scientific development services
48	Advertising and market research services
49	Other professional, scientific and technical services; veterinary services
50	Rental services
51	Services related to employment

52	Services of travel agencies, tour operators and other reservation services, and services related thereto
53	Security and investigation services; services for buildings and landscaping; administrative, office and other business support services
54	Public administration and defense services; mandatory social security services
55	Education services
56	Health care services
57	Social care services in residential establishments; social services without accommodation
58	Creation, artistic and entertainment services; library services, archives, museums and other cultural services; gambling and betting services
59	Sports, recreational and entertainment services
60	Services provided by associations
61	Repair services of computers, personal effects and articles for domestic use
62	Other personal services
63	Household services as employers of domestic personnel; undifferentiated goods and services produced by households for own use

Annex 3: List of atmospheric pollutants considered

CO ₂	Carbon dioxide
N ₂ O	Nitrous oxide
CH ₄	Methane
PFC _s	Polyfluorocarbon compounds
HFC _s	Hydrogenofluorocarbon compounds
SF ₆	Sulfur hexafluoride
NO _x	Nitrogen oxides
COVNM	Volatile organic compounds (except methane)
CO	Carbon monoxide
SO ₂	Sulfur dioxide
NH ₃	Ammonia
PM ₁₀	Particles with a diameter less than or equal to 10 µm
PM _{2.5}	Particles with a diameter less than or equal to 2.5 µm

Annex 4: List of 47 COICOP products and 12 COICOP categories

01 - FOOD AND NON-ALCOHOLIC BEVERAGES

01.1 - Food

01.2 - Non-alcoholic beverages

02 - ALCOHOLIC BEVERAGES AND TOBACCO

02.1 - Alcoholic beverages

02.2 - Tobacco

02.3 - Narcotics

03 - CLOTHING AND FOOTWEAR

03.1 - Clothing

03.2 - Footwear

04 - HOUSING, WATER, GAS, ELECTRICITY AND OTHER FUELS

04.1 - Actual rentals for housing

04.2 - Imputed housing rentals

04.3 - Regular maintenance and repair of the dwelling

04.4 - Other services relating to the dwelling

04.5 - Electricity, gas and other fuels

05 - FURNISHINGS, HOUSEHOLD EQUIPMENT AND ROUTINE MAINTENANCE OF THE HOUSE

05.1 - Furniture, furnishings and decorations, carpets and other floor coverings and repairs

05.2 - Household textiles

05.3 - Household appliances

05.4 - Glassware, tableware and household utensils

05.5 - Tools and equipment for house and garden

05.6 - Goods and services for routine household maintenance

06 - HEALTH

06.1 - Medical products, appliances and equipment

06.2 - Outpatient services

06.3 - Hospital services

07 - TRANSPORT

07.1 - Purchase of vehicles

07.2 - Operation of personal transport equipment

07.3 - Transport services

08 - COMMUNICATIONS

08.1 - Postal services

08.2 - Telephone and telefax equipment

08.3 - Telephone and telefax services

09 - RECREATION AND CULTURE

09.1 - Audio-visual, photographic and information processing equipment

09.2 - Other major durables for recreation and culture

09.3 - Other recreational items and equipment, gardens and pets

09.4 - Recreational and cultural services

09.5 - Newspapers, books and stationery

09.6 - Package holidays

10 - EDUCATION

10.1 - Infant and primary education

10.2 - Secondary education

10.3 - Post tertiary non-tertiary education

10.4 - Tertiary education

10.5 - Teaching not defined by grade

11 - RESTAURANTS AND HOTELS

11.1 - Catering services

11.2 - Accommodation services

12 - MISCELLANEOUS GOODS AND SERVICES

12.1 - Personal care

12.2 - Prostitution

12.3 - Personal effects n.e.c.

12.4 - Social protection

12.5 - Insurance

12.6 - Financial services n.e.c.

12.7 - Other services n.e.c.

Annex 5: Results

**Table A1: Structure of one-person households (OPH) of women by age.
Spain 2008-2013 – Sample**

	2008	2009	2010	2011	2012	2013
Average OPH	64.169	63.541	64.287	64.841	64.311	64.173
≤30	90	82	85	97	79	77
30<;≤45	230	263	237	215	265	315
45<;≤65	533	554	547	592	588	600
<65	1,156	1,133	1,180	1,175	1,166	1,221

**Table A2: Structure of one-person households (OPH) of men by age.
Spain 2008-2013 – Sample**

	2008	2009	2010	2011	2012	2013
Average SF	55.113	54.816	54.534	54.106	54.444	53.709
≤30	78	109	90	101	112	115
30<;≤45	342	339	372	376	399	456
45<;≤65	361	436	465	495	485	494
<65	396	417	406	394	416	420

**Table A3: Structure of one-person households (OPH) of women by quintile of expenditure.
Spain 2008-2013 – Sample**

	2008	2009	2010	2011	2012	2013
Average spending OPH	17,134	17,325	17,254	17,212	17,430	17,082
Q ₁ (higher quintile)	34,355	33,928	33,244	33,031	33,215	31,633
Q ₂	19,180	19,513	19,573	19,487	19,367	19,488
Q ₃	14,151	14,803	14,713	14,730	14,961	14,823
Q ₄	10,949	11,146	11,148	11,243	11,680	11,592
Q ₅ (lowest quintile)	7,080	7,247	7,631	7,610	7,941	7,885

**Table A4: Structure of one-person households (OPH) of men by quintile of expenditure.
Spain 2008-2013 – Sample**

	2008	2009	2010	2011	2012	2013
Average spending OPH	19,057	19,034	18,112	18,876	17,802	17,351
Q ₁ (higher quintile)	37,742	39,024	34,816	37,316	33,824	32,474
Q ₂	21,774	21,076	21,062	21,266	20,352	20,036
Q ₃	16,260	15,855	15,478	16,110	15,770	15,430
Q ₄	12,033	11,727	11,646	12,087	11,655	11,506
Q ₅ (lowest quintile)	7,493	7,503	7,579	7,613	7,420	7,309

**Table A5: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the
consumption basket of one-person households (OPH) of women by age. Spain 2008-2013 –
Sample**

	2008	2009	2010	2011	2012	2013
≤30	7,439	5,485	5,080	4,497	4,451	3,719
30<≤45	7,875	2,506	5,880	5,627	5,105	4,524
45<≤65	7,784	6,923	5,690	5,562	5,581	5,054
<65	5,429	5,142	4,331	4,478	4,700	4,258

**Table A6: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the
consumption basket of one-person households (OPH) of men by age. Spain 2008-2013 –
Sample**

	2008	2009	2010	2011	2012	2013
≤30	8,338	6,045	5,157	4,953	4,352	3,848
30<≤45	8,317	7,392	5,481	5,723	5,478	4,766
45<≤65	7,855	7,151	5,393	5,745	5,303	4,841
<65	5,302	5,091	4,414	4,718	4,704	4,161

Table A7: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women by age. Spain 2008-2013 – Sample

	2008	2009	2010	2011	2012	2013
Q ₁ (higher quintile)	11,642	10,325	5,947	8,322	8,737	7,894
Q ₂	7,007	6,792	5,135	5,467	5,388	4,959
Q ₃	5,664	5,284	4,957	4,449	4,698	4,109
Q ₄	4,796	4,221	4,631	3,817	3,897	3,451
Q ₅ (lowest quintile)	3,008	2,751	3,850	2,476	2,225	2,052

Table A8: Average of greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of men by age. Spain 2008-2013 – Sample

	2008	2009	2010	2011	2012	2013
Q ₁ (higher quintile)	16,191	14,565	9,354	11,460	10,039	8,616
Q ₂	8,381	6,659	5,796	6,141	6,111	5,517
Q ₃	5,360	5,135	4,455	4,422	4,070	3,883
Q ₄	3,377	3,582	3,186	2,905	2,927	2,723
Q ₅ (lowest quintile)	2,500	2,363	2,725	1,993	2,357	2,005

Table A9: Greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of women by COICOP groups. Spain 2008 – Population

COICOP	2009	2010	2011	2012
Food and non-alcoholic beverages	1,614.95	1,383.84	1,432.76	1,391.31
Alcoholic beverages, tobacco, and narcotics	68.96	63.34	66.40	66.57
Clothing and footwear	283.65	250.37	214.86	200.89
Rentals and supplies	2,002.74	1,602.68	1,758.90	1,856.19
Goods and services for home maintenance	311.68	238.15	229.80	205.67
Pharmaceutical products, equipment and material, outpatient and hospital services	217.97	212.82	151.58	184.22
Purchase and transportation services	466.08	446.92	361.77	418.27
Communication	126.95	96.86	95.78	93.55
Recreation and culture	240.16	188.44	181.17	166.02
Education	3.07	3.08	2.94	2.62
Restaurants and hotels	171.14	185.56	178.12	181.94
Miscellaneous goods and services	347.54	239.47	246.10	271.77

Table A10: Greenhouse gases embedded (in thousand tons of equivalent CO₂) in the consumption basket of one-person households (OPH) of men by COICOP groups. Spain 2008 – Population

COICOP	2009	2010	2011	2012
Food and non-alcoholic beverages	1,333.89	1,108.34	1,097.26	1,128.56
Alcoholic beverages, tobacco, and narcotics	157.91	127.79	149.85	134.90
Clothing and footwear	205.79	207.41	184.41	162.32
Rentals and supplies	1,864.98	1,447.47	1,581.78	1,549.67
Goods and services for home maintenance	292.73	197.28	217.85	176.48
Pharmaceutical products, equipment and material, outpatient and hospital services	175.13	106.42	121.00	108.68
Purchase and transportation services	1,448.64	912.17	1,075.91	943.27
Communication	155.89	109.25	106.56	99.34
Recreation and culture	314.94	225.78	236.43	194.39
Education	4.52	5.47	3.61	4.82
Restaurants and hotels	435.99	414.50	477.86	438.92
Miscellaneous goods and services	222.55	177.85	188.58	171.53

The logo consists of the word "UBIREA" in a bold, sans-serif font. The "UB" is in a light blue color, and "IREA" is in a darker blue. The text is set against a white background that is part of a larger blue graphic element.

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