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## Emissions structure: a systemic analysis to Brazilian economy - 2003 and 2009

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# **Emissions structure: a systemic analysis to Brazilian economy – 2003 and 2009<sup>1</sup>.**

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## **Abstract**

In the recent period, there is an increase in the household income in Brazil. There is a positive impact upon consumption and welfare. On the other hand is important to verify the impact upon emissions derived from household consumption. The literature presents two approaches to analyze emissions. They are: account CO<sub>2</sub> emissions based on the production principle and on the consumer principle. According to the consumer principle, the consumer is responsible for CO<sub>2</sub> emissions from the production of energy, goods and services. In this case, the CO<sub>2</sub> emissions are related to final use of goods and services even if they are imported from other countries. In order to reach the main aim of this paper we will use an input-output approach, specifically the extraction method. We use input-output matrix calibrated for 2003 and 2009 for the Brazilian economy considering 35 production sectors. We opened the household consumption into eight income categories. We closed the input-output model for household. This enables us to better understand the impact of each class of consumption upon the CO<sub>2</sub> emissions.

**Key-words:** CO<sub>2</sub> emissions, household consumption, input-output

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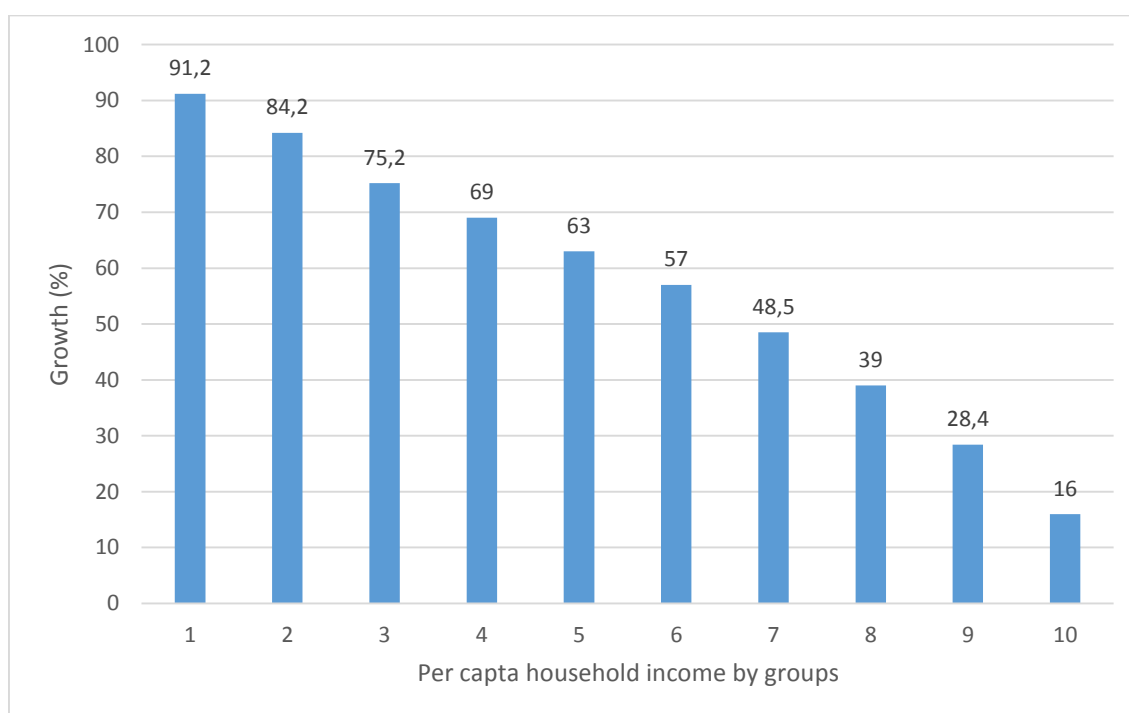
## Emissions structure: a systemic analysis to Brazilian economy – 2003 and 2009.

### 1. Introduction

The Brazil in recent years has experienced a process of economic growth and recovery of income. Clearly, this increase in income has positive impacts on, for example, the consumption of goods. Moreover, this increase in consumption has positive multiplier effects on the economy, because there is the need to offer more goods in the economy to meet a new and growing demand.

Moreover, the production and consumption process often generates a polluting process. Therefore, assessing the impact of changes in income upon emissions is of interest to the literature in order to make a counterpoint to the benefits from the increased income and thus consumption.

**Figure 1 - Growth of household per-capita (2001-2011) income**

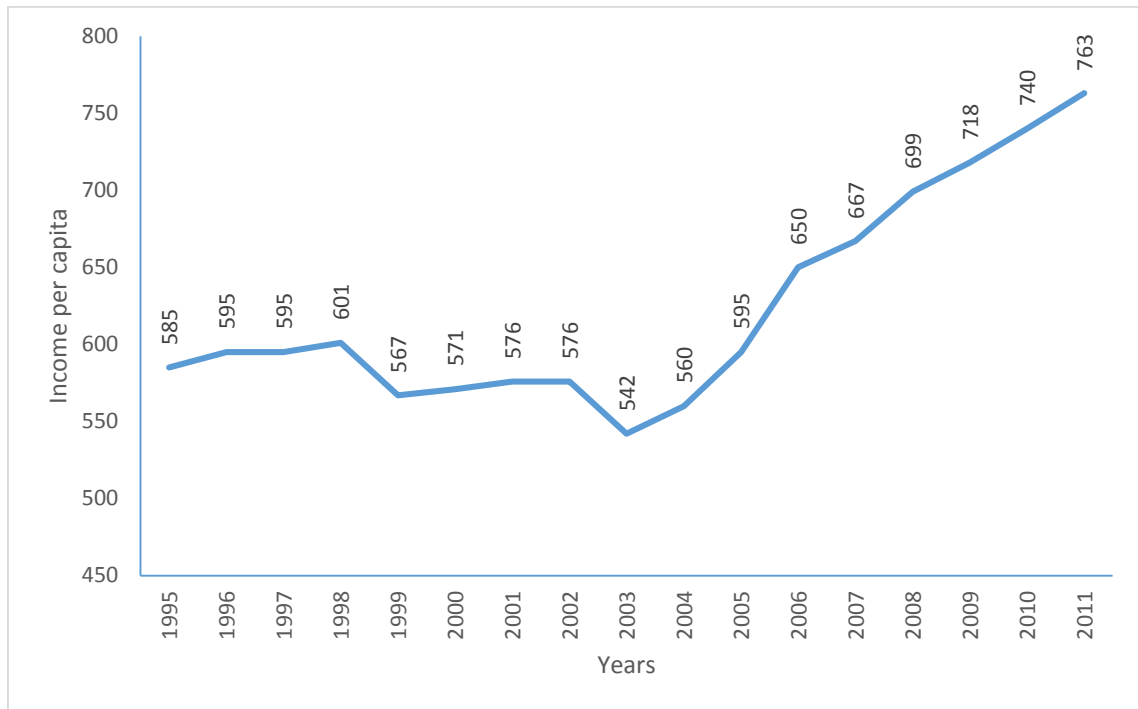


Source: Neri and Souza (2011) based on PNAD

According to Neri and Souza (2011) there was an increase in income between 2001 and 2011. For illustrative purposes, Figure 1 shows such a phenomenon as it shows how the lower strata of income (*e.g* income ranges) had higher growth per-capita income. It is important to note that until the sixth income group growth was greater than 50%. In the same line of argument can also see an increase in average income between 1995 and 2011. Moreover, Figure 2 shows the evolution of average income

for an interval of 16 years, being possible to observe the trend of growth in average income from 2003.

**Figure 2 – Average Income (\$)**



Source: Neri and Souza (2011) based on PNAD

Importantly, the behavior of income for the eight extracts of income adopted in this work for the analysis period (2003-2009). In this period, as expected, there is greater income growth for the extracts of lower income. One example is the annual growth rate of less extract income was 73.55% and the biggest extract income was 19.88%. Table 1 shows the annual growth rates for the other extracts.

**Table 1 Annual growth rate of income: 2003-2009.**

	HH1	HH2	HH3	HH4	HH5	HH6	HH7	HH8
Annual Growth Rate	73,556	43,845	22,879	26,165	38,505	36,572	27,470	19,888

Source: Elaborated by the authors based on POF

Table 2 will show a stable structure of the contribution of CO<sub>2</sub> emissions. The data show that households are responsible for about 22% of emissions as compared to emissions from intermediate consumption. Although no major changes in the analyzed period, the result shows the importance of studying more closely the emissions from the consumption of households in income growth environment.

**Table 2 - Distribution of emissions: Intermediate Consumption and Household Consumption**

	1995	2000	2003	2005	2009
Intermediate	76,3%	77,3%	77,9%	78,1%	77,9%
Household	23,7%	22,7%	22,1%	21,9%	22,1%

Source: Elaborated by the authors based on WIOD

Thus, this study aims to assess the impact of household consumption on the emission of greenhouse gases, more specifically CO<sub>2</sub> emissions. In the present study, households will be divided into eight intervals of consumption using data from the Household Budget Survey (POF), and eight extracts income using data from the National Household Sample Survey (PNAD).

These data will provide the basis for opening the vector of household consumption and the vector of worker's compensation in the input-output matrix. It is important to note that the matrices used are for the years 2003 and 2009. Note that the period of analysis coincides with periods of POF. Besides this introduction, this work presents a literature review, a section of the methodology and database, a section for discussion of results and final considerations

## 2. Literature Review

A series of works that deal with the relationship between household consumption and CO<sub>2</sub> emissions. According to Weber and Perrels, (2000) the life style of people influences mainly for goods in their consumption by energy and how they spend their "time", which in turn directly influences the pattern of emissions. Washizu and Nakano (2010) give a picture of the modification of the "lifestyle" in his studies of Japanese families, derived from the active participation of women in the labor market. From this fact happens a reversal of time of homemakers' economy. Households start to use services such as eating out and pre-packed food, advantageous from the economic point of view. Households fail to make meals at home, thus modifying their pattern of consumption and emissions.

Wier et al., (2001) and Munksgaard et al., (2000) connect the idea of "lifestyle" of the previous pattern of household consumption authors. To do this, use the input-output matrix for dealing with the relationship between household consumption and emissions, whereas the emission arrays can be both direct, and indirect. The differentiation between households should consider several types of socio-demographic variables that may also influence the pattern of consumption, for example, economic issues, demographics, number of children, number of adults aged who maintains residence, urbanity, type accommodation, socio-cultural variables, employment status and education level of those who maintain the residence.

Still addressing the importance of focus on consumption, Perrels and Weber (2000) highlight two reasons to give attention to household consumption. First, for them private consumption is the most important category of final demand in most economies, followed by export production. However, household consumption has an important role in the diversity and volume of commodities produced. Second, a detailed model of household consumption pattern offers an increased possibility of accounting for the effects of non-economic influences on direct and indirect use of energy related to family issues.

Studies make a comparison between the direct and indirect effects of emissions. These studies are classified into two types: a) direct CO<sub>2</sub> emissions - are associated with the consumption of energy goods (electricity, gas, oil, gasoline) and b) indirect CO<sub>2</sub> emissions - associated with the production of all other goods (for example, furniture, clothes, food and services) (Wier et al., 2001; Munksgaard et al, 2000).

Departing for the discussion of responsibility for emissions (producers versus consumers) Davis and Caldeira (2010), Peters (2008) and Davis, Peters, and Caldeira (2011) have significant contributions. The main hypothesis of these authors is a geographical separation between extraction, production and consumption. This separation is a problem when it comes to who is responsible for the issuing process and how policies that limit and responsibility for emissions should be divided.

For which agent we assign the responsibility of emissions. Davis and Caldeira (2011) support if the geographic concentration of natural resources like oil, coal and gas, so that it starts a policy of regulation or accountability. The issue to be addressed is that these regions hold of natural resources will not fail to possess them, or continue exporting or using their resources, regardless of any intensive supervisory policy. Regions that are already in development, ie, the industries have installed these countries Productions carbon intensive character and can migrate from the production site with ease, fleeing from the regulatory authorities. The sum of the foregoing factors leads to the following result, transaction costs will be lower due to the amount of areas that will negotiate the economic burden that will be divided among all beneficiaries of the fuels without much option of escape. However, the mapping of agents help control this. Goods and services consumed in a country can be produced in another country using fossil fuels from a third country. Thus, it is clear the difficulty of capturing the responsible agent in the chain of CO<sub>2</sub> emissions.

To implement this type of analysis (Davis and Caldeira, 2011) using an array of global input-output. This database presents a portrait of the monetary flows between industries or regions (countries). In this type of analysis, it is necessary to consider the following aspects: a) the total production in the economy with sectoral and regional breakdown; b) the sectoral output, which is produced in one country and consumed in another region, c) optical purchase (eg, intermediate consumption) can

also map the amount of inputs required input for a specific industry located in a specific region required to produce one unit of good in another region.

Another view of the division of responsibility for emissions began in the United National Framework Convention of Climate Change (UNFCCC). From this convention, countries have to submit your benchmark emission reduction for national emissions inventory - NEI National Emission Inventories. Thus, there are two new categories: consumption-based and production-based NEI NEI. These categories will be the new final consumers will share the responsibility of emissions at the subnational level. These two categories mentioned above are benefited at the extremes of the chain. NIS indicators are calculated in such a way that the consumer base is NIS exclude exported products, but include imported products, and the production base NIS includes products exported.

This sharing of responsibility is balanced by a weight to each country according to their needs and strategies. Also, note that this calculation is not trivial. Despite some criticism within the literature mentioned in the article Peters (2008) by using this system, due to some adjustments during the implementation of its methodology, the authors arrive at two different results, one that emphasizes clarity of environmental policies and other binding CO<sub>2</sub> consumption using two distinct paths. It is important to emphasize the importance of the union of these results with other indicators which when combined with environmental policy and trade can provide better mitigation for future work aimed at relating the propositions of solutions and political resolutions. (Peters, 2008)

### 3. Methodology and Database

#### *3.1. Compatibility of POF with input-product matrix*

The initial goal was to transform the products of POF 2002-2003 and 2008-2009 in the goods and services that households make up the column vector of Household Consumption (1 × 35) Matrix Input-Output 2003 and 2009 (Table of Uses and Features ). With the aid of tables and pre-established in POF groups, a translator who collapsed the 10,360 items in the POF 35 Products of the input-output matrix was created.

The second step, after pooling expense items, was the construction of a distributed array that spending by 35 different product families for eight classes. Therefore, we opened all households (consumer units) in eight types in the model, following a differentiation by family income per capita (income percentiles). We calculate eight intervals of per capita households' income for the differentiation of households; in which we weighted each yield by its expansion factor of the sample (see Table 3).

**Table 3. The structure of Consumption for opening the income groups**

POF - Consumption Database					
		2003		2009	
Household 1	lower than	96,00		186,70	
Household 2	between	96,00	158,87	186,70	297,00
Household 3	between	158,87	227,66	297,00	422,43
Household 4	between	227,66	310,41	422,43	570,02
Household 5	between	310,41	432,50	570,02	767,91
Household 6	between	432,50	641,23	767,91	1.095,55
Household 7	between	641,23	1.156,46	1.095,55	1.833,58
Household 8	above	1.156,46		1.833,58	

### 3.2. Hypothetical Extraction Method

According to Miller and Blair (2009) the purpose of the hypothetical extraction method is quantified as the total output of an economy with  $n$  sectors can be modified (e.g decrease) if a particular sector, say the  $j$ th, is removed from the economy. We can performed this extraction in three ways: a) total extraction industry (or agent) - columns and rows; b) extracting the structure of purchases (e.g backward linkages) - extraction of the columns; c) extraction of the sales structure (e.g forward linkages) - extraction of lines. For this paper, the interest is in extracting the structure of purchases.

Therefore, consider the general case of an input-output model closed to households with  $n$  productive sectors and  $m$  households. Therefore, the model in with the endogenous households the matrices will be in size  $(n + m) \times (n + m)$ . The model is given by:

$$x = A^* x + f^* \quad (1)$$

Where:  $x$  – is the column vector product with  $(n + m)$  elements.

$A^*$  – is the matrix  $(n + m) \times (n + m)$  of input coefficients.

$f^*$  – is the column vector of final demand with  $(n + m)$  elements (1)

The solution of equation (1) will be:

$$x = (I - A^*)^{-1} f^* \quad \text{ou} \quad B^* f^* \quad (2)$$

where  $B^* = (I - A^*)^{-1}$  is the Leontief Inverse



Therefore, using the above structure it is possible to draw the impacts of hypothetical extraction of a particular industry/sector/agent. In the present article, extraction will occur in elements of household consumption. In other words, we retrieve the consumption structure of each of the extracts of household consumption. Generally, we can say that the *j*-th sector / agent does not acquire inputs in the productive sectors. With this procedure, we would be pulling backward links.

The new matrix  $A^*$  is represented by  $\bar{A}_{(cj)}^*$ . Where  $\bar{A}_{(cj)}^*$  is the representation of hypothetical extraction of the *j*th column of the matrix  $A$ .

Therefore, the solution of this problem would be:

$$\bar{x}_{(cj)}^* = [I - \bar{A}_{(cj)}^*]^{-1} f^* \quad (3)$$

Comparing equation (2) and (3) it is possible to calculate the impact of the extraction of backward links, as follows:

$i'x^* - i'\bar{x}_{(cj)}^*$  - Measure of the total link back to sector *j*.

The result can also be disaggregated to the sectors. Thus, we have that every element  $x_i - \bar{x}_{(cj)i}^*$  can be seen as the backward dependence of the sector *j* relative to sector *i*.

### 3.3. Impact on emissions

The calculations presented in Section 3.2, therefore, provide the impact on production due to the extraction of the structure of household consumption and can be interpreted as the change in output of the economy due to the extraction of the structure of household purchases.

Therefore, to verify the impacts on emissions will be necessary to translate the impact on production, ie, the decrease in production, in terms of emissions. To this end, we use the vector of emission intensity, which is the ratio between emissions and gross value of production, represented by:

$$e_i = \frac{E_i}{VBP_i} \quad (4)$$

Where:  $e_i$  - Vector of emission intensity

$E_i$  - Sectoral CO<sub>2</sub> emissions.

$VBP_i$  - Gross value of sectoral output.

We implement the calculation of the impact of the extraction of each group of families on emissions as follows:

$$Emiss\tilde{o}es_i^I = diag(e_i^I) * (x_i^I - \bar{x}_{(c_j)i}^I) \quad (5)$$

Where:

$Emiss\tilde{o}es_i^I$  – Emissions - CO2 emissions for the family group I and sector i

$diag(e_i^I)$ - diagonal matrix of the vector of emission intensity for the family group I.

$(x_i^I - \bar{x}_{(c_j)i}^I)$ - backward dependence of sector j relative to sector i.

Important to note that in the case of this work I = 1, ..., 8 and i = 1, ..., 35.

### 3.3. Database

This work made use of the following databases:

- a) input-output matrices for the years 2003 and 2011 These matrices were calibrated to 35 productive sectors and were drawn from the World Input-Output Database (WIOD) - [www.wiod.org](http://www.wiod.org).
- b) Household Budget Survey for the years 2002-2003 and 2008-2009.
- c) National Sample Survey for the years 2003 and 2009.
- d) Structure of emissions - [www.wiod.org](http://www.wiod.org)

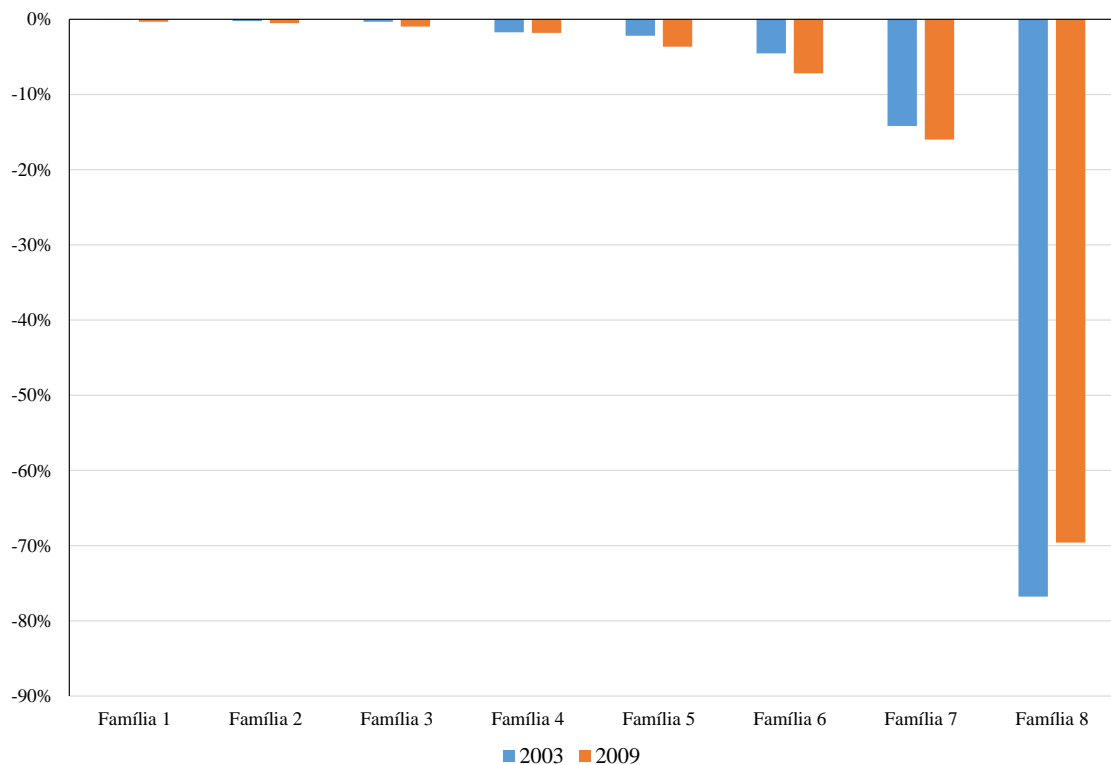
### 4. Results

Figure 3 shows the ratio of the impact on emissions of the production system according to the eight families segments considered in 2003 and 2009. This figure indicates that the extract of consumption and income represented by the Family 8, when removed from the analysis, produces greater negative impact on emissions than other extracts. This effect is more concentrated in 2003 than in 2009. Others extracts family produce greater emission reductions when removed from the analysis in 2009 than in 2003.

Figure 4 depicts the ratio of the impact on sectoral emissions in accordance family segments in 2003 and 2009. Such a figure is indicative of how the structure of consumption and income of each family group systemically affects the production and, consequently, sectoral emissions. Panel A shows the results for the Family 1. In

this case, the structure of consumption and income of this family group affects the economy so that sectors such as agriculture, hunting, forestry and fishing (C1), Electricity, gas and water (C17) and Ground Transportation (23) are the most negatively impacted in terms of emissions in 2003. expected result, given that family low income groups tend to have a structure that spending more intensively mobilize inputs related to the food production chain, transportation and provision of basic services. The withdrawal of this family group becomes more present (or apparent or perceived), so with larger negative effects on production and emissions from these sectors.

**Figure 3. Proportion of the impact on emissions according to the household extracts**



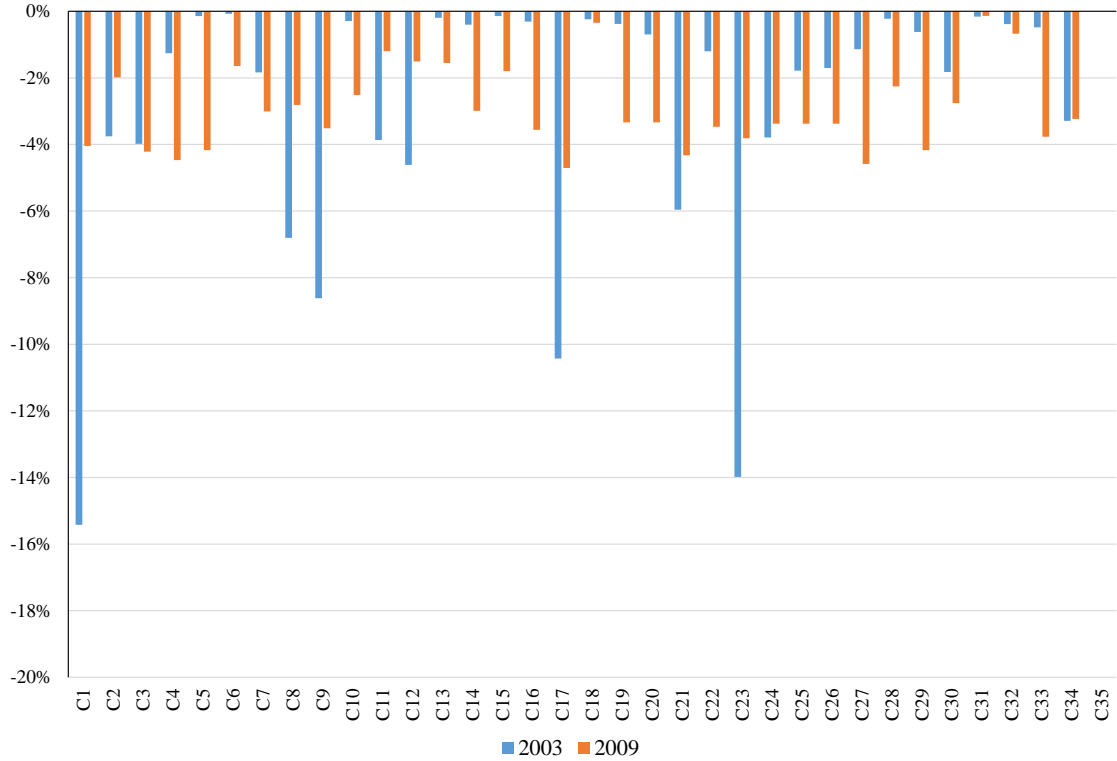
Source: Elaborated by the authors based on model results.

As the other panels are observed, with a projection of the results to other family groups in ascending order of income, no change in the pattern of the proportion of the most affected sectors. The transportation sector presents two peculiarities in this process, particularly in 2003. The first is that family level extracts with higher incomes more strongly mobilize the economy, including the transportation sector. Thus, the higher the income level the higher family statement tends to be the effect on the transportation sector. The second peculiarity is that the transportation sector has one of the highest ratios of emission intensity (see table of APPENDIX I) that year. Thus, we have coupled two effects that provide the important role of transport sector in terms of emissions reduction.

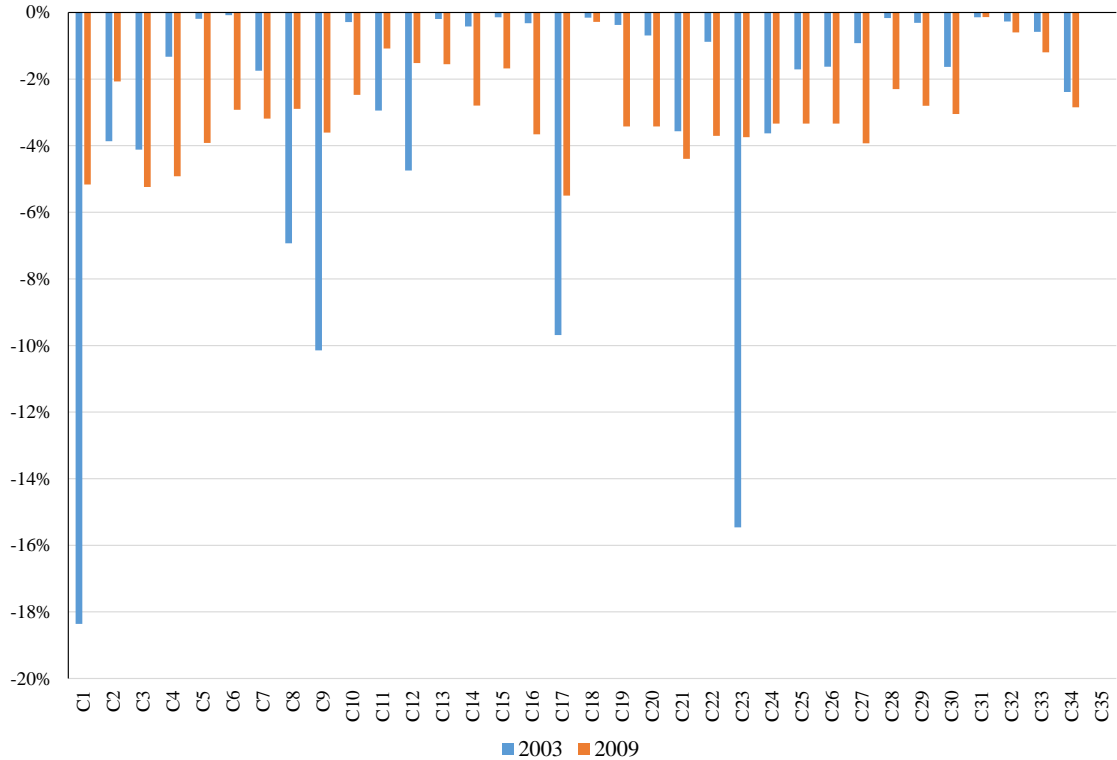
In this process, when analyzing the withdrawal in order of increasing family extracts with higher income, the effects tend to be less concentrated. Sectors such as coke, refined petroleum products and nuclear fuel (C8), chemicals and chemical products (C9) and basic and fabricated metals (C12) now have greater proportion of emissions in the fall.

The obvious differences of the impact on emissions between 2003 and 2009 is due to the two effects mentioned above when a familiar extract is removed from the analysis: i) systemic effect on production and ii) the effect of emissions coefficient. In 2009, it is noticed some major changes in the coefficients of emission intensity compared to 2003. Coefficients emissions standard deviation in 2009 was approximately equal to 1, while the coefficients of the standard deviation in 2003 was equal to 0.65. Therefore, the variability of the coefficients of emission intensity partly explains the difference in results between 2003 and 2009 (see Annex I).

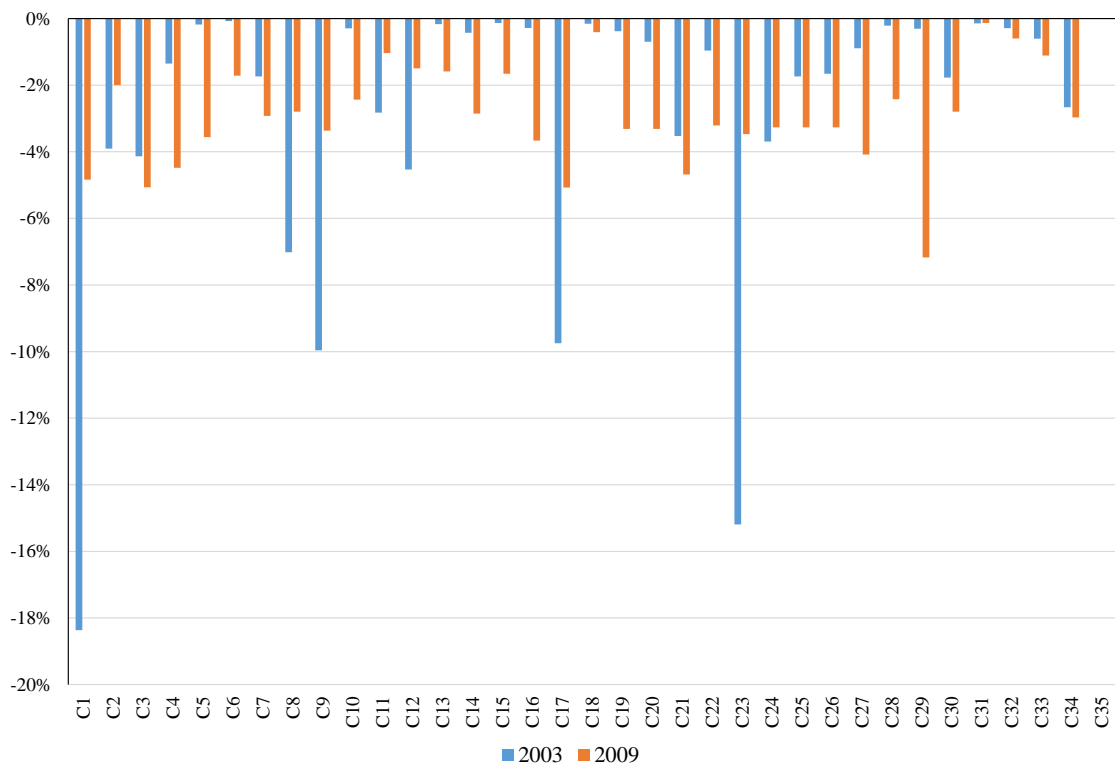
**Figure 4. Proportion of impact on sectoral emissions under the households extracts**  
**(a) Household 1**



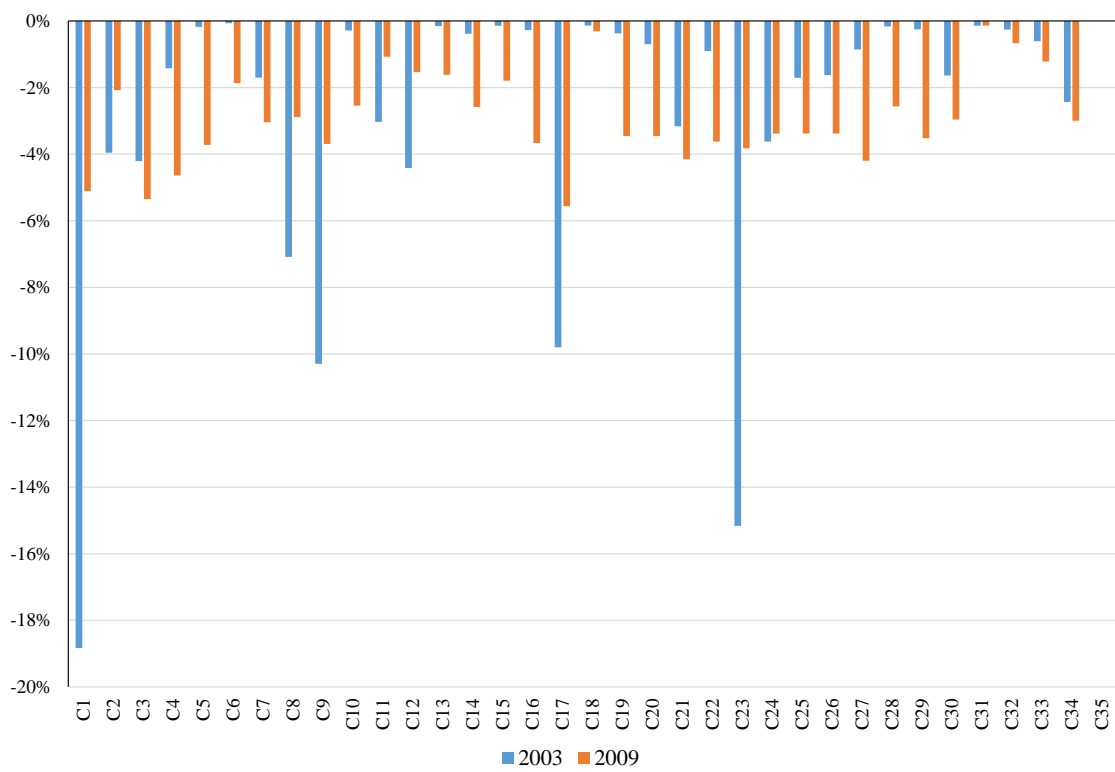
**(b) Household 2**



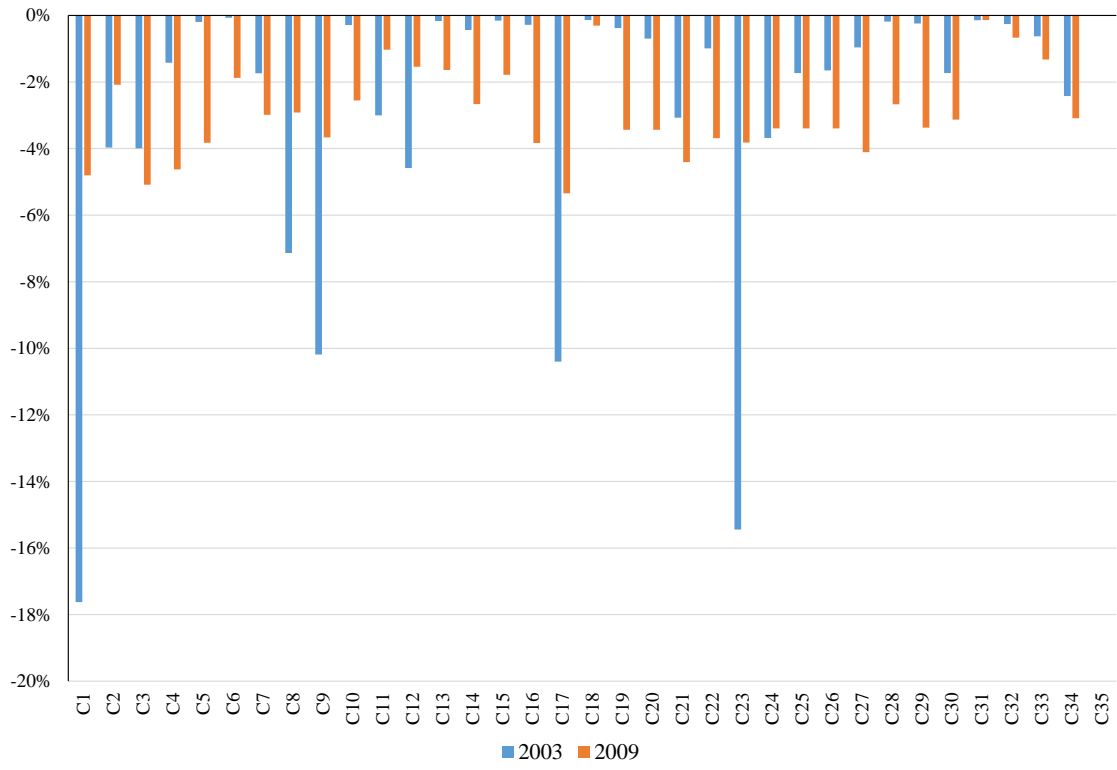
(c) Household 3



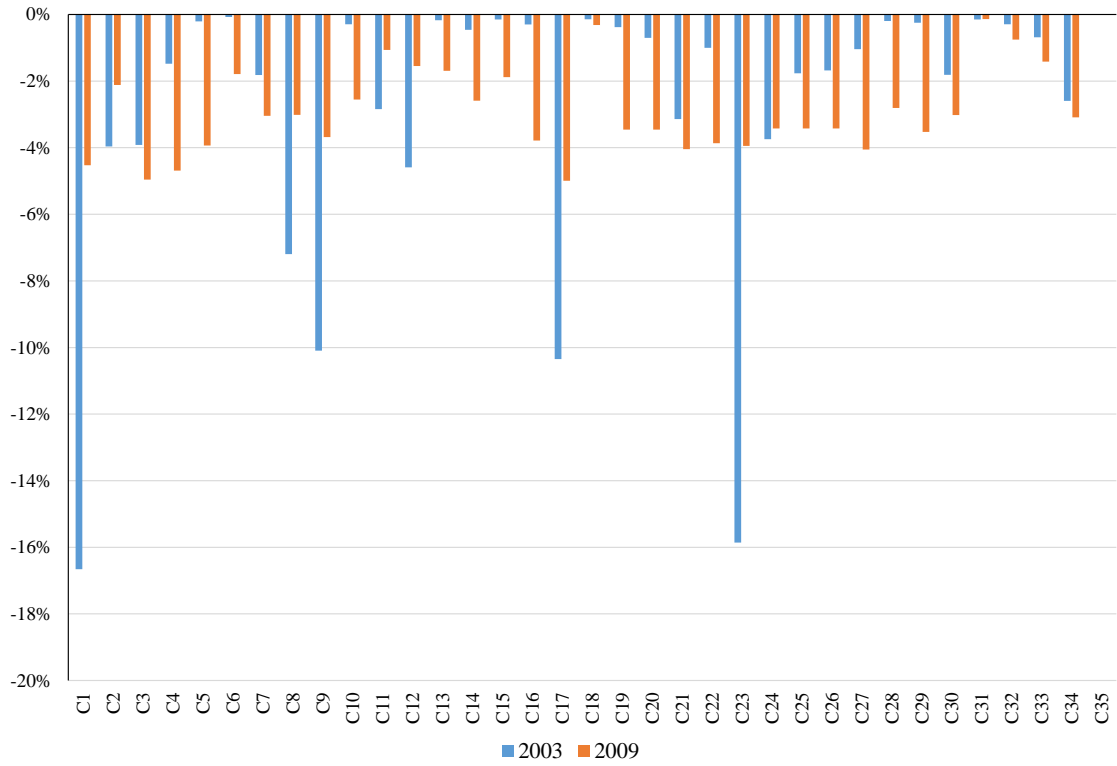
(d) Household 4



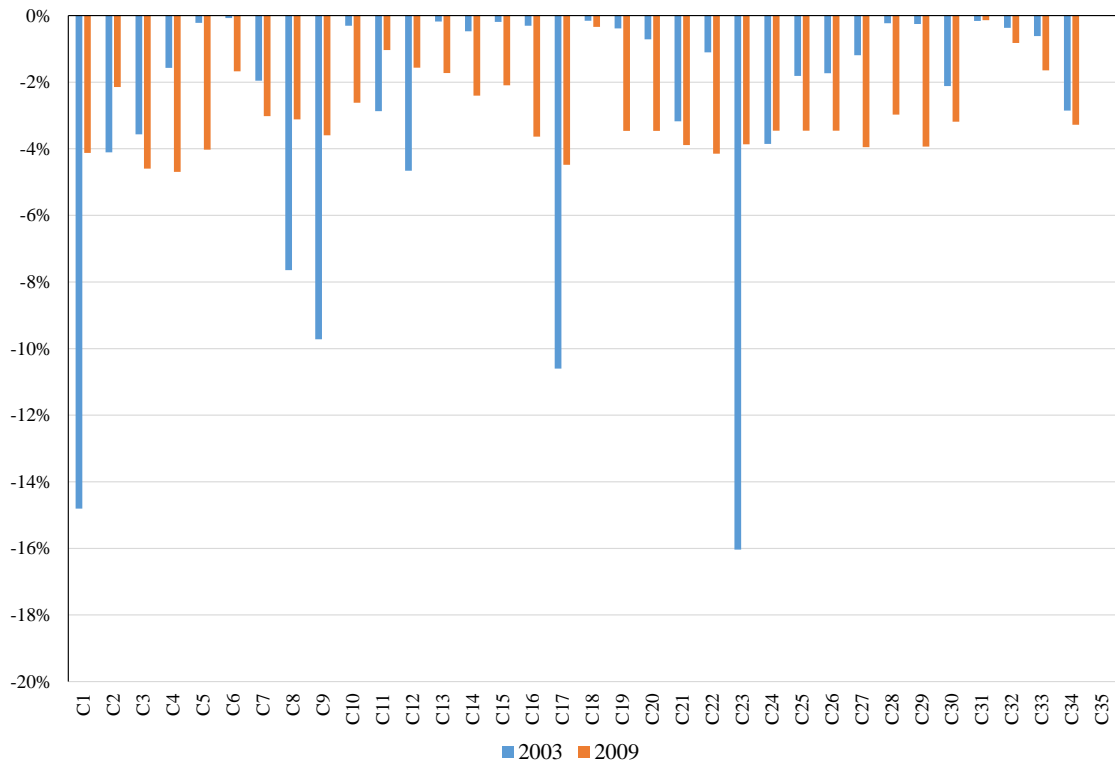
(e) Household 5



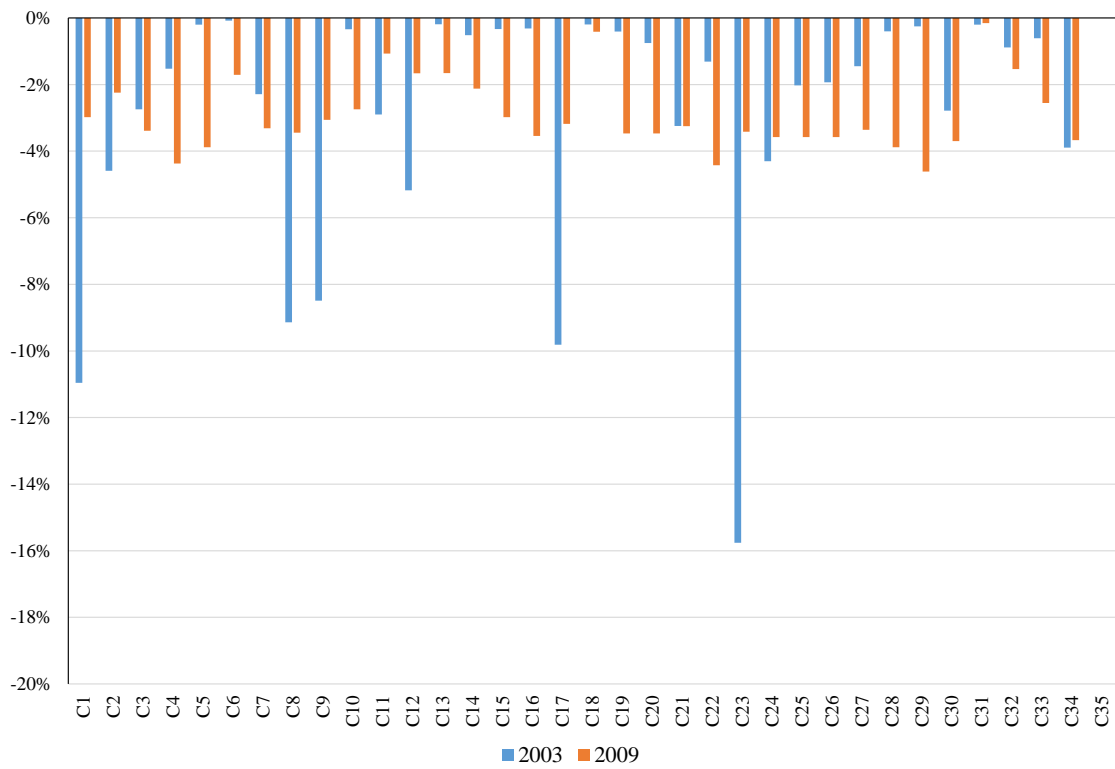
(f) Household 6



(g) Household 7



(h) Household 8





## Final Remarks

This study evaluated the issue of emissions relating to families in a longitudinal context for Brazil using input-product and a database of emissions. By implementing, the method of extraction was possible to show how the hypothetical extraction of a group of families (eg disaggregated into eight extracts) and therefore the abdication of consumption would impact emissions.

The input-output structure allows us to highlight the impacts in its systemic form. Therefore, contributed to this result the structure of sectoral interdependence. Longitudinally to evaluate the process emissions result shows that given the process of sectoral interdependence and given the variations in the emissions coefficient are decreased emissions in the second period. This result is of great importance in the context in which the issue is being addressed.

It's worth noting some results: a) the behavior of the transport sector - evidenced the relative importance of this sector in the emissions scenario and the behavior of slump over the analysis period for all families used extracts; b) the behavior of the agricultural sector - which has, like most other industries, a decrease in the emission process. Also, note that this behavior is more pronounced in the lower strata of consumption; c) the behavior of the service sector - this group of sectors are the least impacted.

An important fact is that the results are in line with the arguments that it is important to assess emissions giving special attention to household consumption. This, in most countries, is the most important component of final demand and therefore has an important role in terms of the multiplier effect of growth. And, in this paper we report the logic of consumption (consumption or not - given the extraction of vectors of consumption) to account for the effects of the influence of a lower consumption and towards an emission assessment.

As extensions of this work can make a decomposition analysis of emissions in longitudinal terms, evaluating emissions in terms of direct, indirect, and total intensity.

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## Annex I

CODE	Description	Intensity Coefficient	
		2003	2009
1	Agriculture, Hunting, Forestry and Fishing	0,4007	0,1674
2	Mining and Quarrying	0,5529	0,3172
3	Food, Beverages and Tobacco	0,0709	0,1360
4	Textiles and Textile Products	0,1239	0,6014
5	Leather, Leather and Footwear	0,0650	1,8065
6	Wood and Products of Wood and Cork	0,0789	2,1445
7	Pulp, Paper, Paper , Printing and Publishing	0,2202	0,5697
8	Coke, Refined Petroleum and Nuclear Fuel	0,4452	0,2727
9	Chemicals and Chemical Products	0,4005	0,2271
10	Rubber and Plastics	0,0665	0,7894
11	Other Non-Metallic Mineral	1,9169	0,9612
12	Basic Metals and Fabricated Metal	0,7965	0,2233
13	Machinery, Nec	0,0468	0,4256
14	Electrical and Optical Equipment	0,0734	0,4086
15	Transport Equipment	0,0264	0,2117
16	Manufacturing, Nec; Recycling	0,0631	1,0864
17	Electricity, Gas and Water Supply	0,4925	0,3192
18	Construction	0,0713	0,1947
19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0,0966	0,9143
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	0,0478	0,2809
21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0,1423	0,1882
22	Hotels and Restaurants	0,0957	0,4396
23	Inland Transport	0,9442	0,3071
24	Water Transport	3,3774	5,4622
25	Air Transport	0,9456	3,4205
26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	0,2463	0,6478
27	Post and Telecommunications	0,0933	0,3903
28	Financial Intermediation	0,0101	0,1691
29	Real Estate Activities	0,0067	0,2069
30	Renting of M&Eq and Other Business Activities	0,0776	0,1560
31	Public Admin and Defence; Compulsory Social Security	0,0922	0,1170
32	Education	0,0691	0,2666
33	Health and Social Work	0,0437	0,2709
34	Other Community, Social and Personal Services	0,1837	0,2792
35	Private Households with Employed Persons	0,0000	0,0000
	Average	0,3540	0,6970
	Standard Deviation	0,6520	1,0690

Source: Elaborated by the authors