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Economic structure and key sectors analysis of greenhouse gas emissions in Uruguay

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Economic structure and key sectors analysis of greenhouse gas emissions in Uruguay

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Abstract

This paper identifies the key sectors in greenhouse gas emissions of the Uruguayan economy through input–output analysis. This allows to precisely determine the role played by the different productive sectors and their relationship with other sectors in the relation between the Uruguayan productive structure and atmospheric pollution. In order to guide policy design for GHG reduction, we decompose sectors liability between the pollution generated through their own production processes and the pollution indirectly generated in the production processes of other sectors.
The results show that all the key polluting sectors for the different contaminants considered are relevant because of their own emissions, except for the sector Motor vehicles and oil retail trade, which is relevant in CO_2 emissions because of its pure, both backward and forward, linkages. Finally, the best policy channels for controlling and reducing GHGs emissions are identified, and compared with the National Climate Change Response Plan (NCCRP) lines of action.

Keywords: Greenhouse gas emissions, input–output, Key sectors, Uruguay.
JEL classification: C67, Q40, Q43, Q56

1. Introduction

There is full consensus on the close link between economic growth, renewable and nonrenewable natural resources use intensity and environmental degradation since the 1972 Stockholm conference (PNUMA, 2002). In this sense, productive structure plays a salient role in the kind of relation between the economy and environment.

The Uruguayan National Development Strategy (ENS) (OPP, 2009) discusses the impact of different stages of economic development on export potential and employment through input–output analysis (IOA). However, while the report highlights the problem of climate change and its necessary consideration for the development of long-term scenarios, the environmental dimension is not taken into account in their empirical analysis.

IOA extended to the environmental dimension allows for a more complete understanding of the relationship between the economy and material flows, which is essential for fully understanding environmental problems and the policy design to solve them (Hoekstra, 2005). Hirschman (1958) suggested IOA use for the identification of key sectors in the economy, measuring the structural interdependence through the backward and forward inter-sectoral linkages proposed by Rasmussen (1956), arguing that economic development and structural change is driven through sectors with above-average linkages. Thus, a relatively small number of sectors whose first impulse may produce small changes may ultimately strongly affect the economy as a whole.

Sectors with greater linkages generate greater externalities, meriting government intervention (Jones, 1976). Thus, key sectors analysis extended to the environmental dimension enables to allocate sectors' responsibility in reference to resource depletion and environmental degradation. Solution to these problems must be addressed both from a technical and economic standpoint. Key sectors analysis is useful to get deep in some of these problems, particularly which kind of policies can be carried out, which sectors would be involved, and which are their relations with other sectors (Alcántara, 2007).

Moreover, IOA extended to other dimensions allows planning exercises with multiple objectives. This is important because it allows taking into account sustainable development targets in the strong sense, considering system biophysical constraints (Miller and Blair, 2009).

Thus, the analysis of key sectors in greenhouse gases (GHGs) emission in Uruguay, both in terms of demand and supply, and taking into account the weight of the sectors in the economy, will help to assign emissions responsibility to productive sectors. Once key sectors are identified, the nature of the relationship will be discussed, because policy recommendations are different if the sector is a polluter through its own production process, or if it is key because it encourages other sectors to produce inputs that have such consequences. This kind of study allows taking into account emissions in prospective analysis, as the OPP (2009) one. It also allows developing indicators on the relationship between different sectors of the economy and the environment.

The general objective of this paper is to identify key polluting sectors of the Uruguayan economy in order to orientate energy and environmental policy. In this sense, two specific objectives are defined: i) determining productive sectors liability, either own and pure, through both its forward and backward linkages in relation to greenhouse gases emissions, and ii) organizing detailed data for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) with productive activities and to relate these with National Accounts structure, approaching to a proposal of environmental accounts for Uruguay. Further analysis of the relationship between the Uruguayan productive structure and the environment helps to give guidelines about specific policy design and government intervention for each problem, according to the role of each of the sectors. Sectors with different level and kind of linkages deserve different kind of policies. In this way, the present paper will help to properly design policies to reduce the environmental pressure and impact of the Uruguayan economy.

Next section details the methodology and data employed. Section 3 shows and discusses the empirical results. Section 4 discusses policy implications based on the analysis above. Section 5 concludes.

2. Methodology

There has been large debate around the key sectors concept, since Rasmussen/Hirschman's traditional approach[1], which still evolves today. The concept was further elaborated by Sonis et al. (2000) based on a minimum information approach. Other advances in order to avoid multipliers biases have also been done. Among them, through the elements of the dominant eigenvectors of the technological coefficients matrix (Dietzenbacher, 1992), the hypothetical extraction method (Paelinck et al., 1965 and Strassert, 1968), graph theory application (Guerrero and Ordaz, 1995), the net multiplier formulation (Oosterhaven and Stelder, 2002; and Dietzenbacher, 2005), the fuzzy clustering analysis (Diaz et al., 2005), or the supply and use tables (Rueda-Cantuche and Amores, 2010).

Key sectors analysis can be generalized to any vector of sectoral coefficients. Alcántara (1995) applies it, through forward and backward linkages, to SOx emissions in Catalonia, Spain, while Lenzen (2003) applies it to energy consumption, land disturbance, water use and GHGs, NO_x, and SO_2 in Australia. It has also been applied to water use in Spain (Duarte et al., 2002) and water consumption in Andalusia, Spain (Velázquez, 2006). Finally, it has been applied also in reference to CO_2 emissions in Spain (Alcántara, 2007a; and Alcántara and Padilla, 2006), and Brazil (Imori and Guilhoto, 2010), and energy consumption in Spain (Alcántara and Padilla, 2003; and Alcántara et al., 2010).

Alternative perspectives on economic interdependence should not be regarded as exclusive, but as complementing each other (Sonis et al., 2000). In addition to key sectors analysis, it is important to decompose linkage multipliers into own and pure components. It is not only important to see if a sector is relevant, but also if it is relevant because it involves many other sectors or it draws heavily on it, or other few sectors. Relevant policies will vary depending on the nature of sectors linkages (Alcántara et al., 2010). Next two subsections describe the methodology employed in the empirical analysis.

[1] Hewings (nd), Lezen (2003) and Miller and Blair (2009) present comprehensive surveys on key sector analysis evolution.

2.1 Key sectors analysis - Rasmussen/Hirschman's approach and extensions

Key sectors analysis from a demand-driven perspective is based on Leontief (1936) model, so assumptions and criticisms to this one has to be considered[2]. Following Hazari (1970), the analysis departs from Leontief's model identity, $\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}}\boldsymbol{y}$, which denotes the relation between total output levels ($\boldsymbol{x}$) required in an economy to hold a final demand vector ($\boldsymbol{y}$) through the inverse Leontief matrix (or matrix of coefficients of direct and indirect requirements per unit of final demand)[3]. Matrix $\boldsymbol{A}$ is the Leontief technical coefficients matrix, whose elements, a_{ij}, depict the weight of how much sector *j* purchases to sector *i* in relation to total sector *j* production.

Key sectors in reference to central planner's preferences function showing the increase in the level of gross output required to hold a unit increase in final demand are defined by the columns sums of $\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}}$. In this way, $\sum_{i=1}^{n} l_{ij}$ denotes the whole increase in gross output required to hold a unit increase in y_j (where l_{ij} are the elements of $\boldsymbol{L}$). In order to avoid biased conclusions, multipliers have to be weighted. If not, small sectors that take a relevant part of their input from other sectors will have relevant multipliers, while in fact their weight in total production is not very relevant. So, if $\widetilde{y}_i = \frac{y_i}{\sum_i y_i}$ and $\sum_i \widetilde{y}_i = 1$ demand-driven multipliers (backward linkages) can be rewritten, such that $\boldsymbol{\xi_y}' = \boldsymbol{u}'(\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}}\widehat{\widetilde{\boldsymbol{y}}}$, where $\boldsymbol{u}_{nx1}$ is a summation vector.

Jones (1976) argues that supply-side multipliers (forward linkages) must be measured departing from Ghosh (1958) model. So, solving the system $\boldsymbol{x}' = \boldsymbol{v}'(\boldsymbol{I} - \boldsymbol{D})^{-\mathbf{1}}$, where $\boldsymbol{G} = (\boldsymbol{I} - \boldsymbol{D})^{-1}$ is the Ghosh inverse[4] that denotes the total output level ($\boldsymbol{x}$) that an economy has to produce to sustain a unit increase of primary inputs ($\boldsymbol{v}$), weighted forward linkages multipliers can be defined as $\boldsymbol{\xi_v} = \widehat{\widetilde{\boldsymbol{v}}}(\boldsymbol{I} - \boldsymbol{D})^{-\mathbf{1}}\boldsymbol{u}$, where $\widetilde{v}_i = \frac{v_i}{\sum_i v_i}$ and $\sum_i \widetilde{\boldsymbol{v}}_i = 1$.

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[2] Leontief model is entirely a static analysis. This implies to assume that the interindustry flows from *i* to *j* – recall that these are for a given period, say a year – depend entirely on the total output of sector *j* for that same time period. Other main assumption of the model is that technical coefficients are viewed as measuring fixed relationships between a sector's output and its inputs, assuming constant returns to scale, ignoring economies of scale in the production process. In addition, IOA requires that a sector use inputs in fixed proportions. Pulido and Fontela (1993) and Miller and Blair (2009) present a full review of the Leontief (1936) model.

[3] In this paper, elements in **bold** denote vectors and matrices (lowercase and uppercase, respectively), while the scalars will be expressed in plain text. In turn, the ^ symbol over a vector element refers to a diagonal matrix composed of the specified vector.

[4] Symmetrically to Leontief inverse: $(\boldsymbol{I} - \boldsymbol{D})^{-1} = \widehat{\boldsymbol{x}}^{-1}(\boldsymbol{I} - \boldsymbol{A})^{-1}\widehat{\boldsymbol{x}}$

In this way, and defining the average multiplier as $\xi = \frac{\boldsymbol{\xi_y}'\boldsymbol{u}}{n} = \frac{\boldsymbol{\xi_v}'\boldsymbol{u}}{n}$, key sectors are those that $\xi_y > \xi$ and $\xi_v > \xi$, while sectors that only satisfy the first or second condition are classified as demand driving or supply driving key sectors respectively. Also, for avoiding classification biases because of outliers, the threshold can be defined in reference to the median multiplier.

Leontief and Ghosh models together can only be used as descriptive tools. When the demand-driven model is used for impact analysis, a crucial assumption is that the direct input-coefficients matrix, $\boldsymbol{A}$, is constant. So, and as a consequence of the straight relation between $\boldsymbol{A}$ and $\boldsymbol{D}$, this means that the coefficients of $\boldsymbol{D}$ cannot remain constant. This problem is known as the "*joint stability problem*" (Chen and Rose, 1986). The coefficients associated with each model can only be stable at the same time if the relative change in total output is the same across all industries (Chen and Rose, 1986 and Dietzenbacher, 1989). Thus, the Ghosh model cannot be interpreted in a physical, causal sense, because $\boldsymbol{D}$ does not quantify the amount of output generated by an injection of primary inputs, but instead indicates how primary inputs depend on further processing (Lenzen, 2003). As a consequence, the Ghosh model can be used as a descriptive tool for comparative studies and for linkages and key sectors analysis, but not for impact studies (Oosterhaven, 1988).

Weighting multipliers by final demand and value added avoids overweighting sectors with a small part of their product used as input by other sectors, but being the main input of small sectors. But it still can happen that an increase in the final demand for the product of a particular sector with high multipliers does not affect many other sectors. This would happen in sectors that draw heavily on one or few sectors only. Rasmussen (1952) proposes a complementary approach to control for sensitivity to extreme values consisting in measuring multipliers variability by the indices of coefficient of variation. From a demand perspective, it is defined as:

(1) $$CV_j^y = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(l_{ij} - \frac{1}{n}\sum_{i=1}^{n} l_{ij}\right)^2}}{\frac{1}{n}\sum_{i=1}^{n} l_{ij}}$$

while from a supply perspective it can be defined as:

(2) $$CV_i^v = \frac{\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(g_{ij}-\frac{1}{n}\sum_{j=1}^{n}g_{ij}\right)^2}}{\frac{1}{n}\sum_{j=1}^{n}g_{ij}}$$

where g_{ij} are the elements of the Gosh inverse matrix ($\boldsymbol{G}$). A high value of $CV_{\boldsymbol{j}}^{\boldsymbol{y}}$ can be interpreted as a sector that draws heavily on one or a few sectors, while if its value is low, it depicts a sector that buy inputs evenly from other sectors. $CV_{\boldsymbol{i}}^{\boldsymbol{v}}$ can be interpreted analogously.

The analysis above can be generalized to any other relevant dimension. For our purpose, it is relevant to extend it taking into account environmental pressure. Alcántara (2007b) defines matrix $\boldsymbol{C} = [\boldsymbol{C_{tj}}]_{\boldsymbol{m*n}}$, where $j = 1, \dots, n$ are the number of economic sectors and $t = 1, \dots, m$ are different environmental degradation dimensions. In that way $\boldsymbol{c_{tj}}$represents the environmental degradation of type *t* per output unit of sector *j*.

From the above, considering a vector column from matrix $\boldsymbol{C}$, vector $\boldsymbol{c}_{nx1} = \begin{pmatrix} c_1 \\ \vdots \\ c_n \end{pmatrix}$ can be written, a vector of coefficients that relates every sector with a particular environmental dimension (either resource use or pollution), such that $\boldsymbol{c}'\boldsymbol{x} = E$, where $\boldsymbol{x}$ is the sector production vector and E is a scalar that denotes the total resource use or pollution generation, depending on the environmental dimension chosen. In this way $\boldsymbol{e}_{nx1} = \hat{\boldsymbol{c}}(\boldsymbol{I}-\boldsymbol{A})^{-\boldsymbol{1}}\boldsymbol{y}$ is defined, where $\boldsymbol{e}$ is a vector representing the direct sector relationship with the environment, where matrix $\boldsymbol{F_y} = \hat{\boldsymbol{c}}(\boldsymbol{I}-\boldsymbol{A})^{-\boldsymbol{1}}$ is a linear operator that converts final demand variations in variations in the emission vector. Analogously, $\boldsymbol{F_s} = (\boldsymbol{I}-\boldsymbol{D})^{-\boldsymbol{1}}\hat{\boldsymbol{c}}$ is a linear operator that converts primary inputs variations in variations in the emission vector.

Similarly to above, demand driven weighted multipliers (weighted backward linkages) extended to GHGs emissions are defined as:

(3) $$\mu'_{\mathbf{y}_{1xn}} = \mathbf{u}'\hat{\mathbf{c}}(\mathbf{I}-\mathbf{A})^{-1}\hat{\hat{\mathbf{y}}}$$

while supply driven weighted multipliers (forward linkages) extended to GHGs emissions are defined as:

(4) $\mu_{v_{1xn}} = \hat{\hat{v}}(I\text{-}D)^{-1}\hat{c}u$

In this way, it is possible to identify the vector of total emission generated per final demand unit (total pollution potential of different sectors from a demand perspective, backward linkage) from the demand-driven model, and the total emission generated as a consequence of the extra primary inputs that are needed to increase the supply of sector-*i*, from a supply-driven model. As above, the multipliers are classified in relation to the average multiplier $\boldsymbol{\mu} = \frac{\mu_y{'}\boldsymbol{u}}{n} = \frac{\mu_v{'}\boldsymbol{u}}{n}$. Coefficients of variation can be computed analogously than before, but in reference to $\boldsymbol{F_y}$ and $\boldsymbol{F_s}$.

2.2 Own and pure components decomposition

In addition, it is important to distinguish if sectors pollute through their own production process or whether they are polluting indirectly through the production processes of other sectors. This task is very important for policy design, because different polluting nature will deserve different policy measures.

Following Alcántara et al. (2010), backward and forward linkages own and pure components decomposition can be made by subtracting the diagonal elements of matrix $\boldsymbol{F_y}$ or $\boldsymbol{F_v}$ respectively from each multiplier. Departing from (1), total GHGs emissions of sector *j* per unit of total final demand can be defined as $\boldsymbol{\mu_{y_j}} = \sum_{i=1}^{n} \boldsymbol{F_{y_{ij}}}\tilde{y}_j$. Thus, the "own backward component" can be written as:

(5) $\boldsymbol{\mu_{y_j}^{own}} = \boldsymbol{F_{y_{jj}}}\tilde{y}_j$

and the "pure backward component" as:

(6) $\boldsymbol{\mu_{y_j}^{pure}} = \sum_{i \neq j} \boldsymbol{F_{y_{ij}}}\tilde{y}_j$

The own backward component tells how variations in the final demand for the products of a sector affect GHGs emissions of the sector itself, while the pure backward component must be understood as how variations in the final demand for the products of a sector affect GHG emissions from other sectors.

In the same way, it is possible to decompose forward linkages. Departing from (2), total GHGs emissions per unit of product for any good can be defined as $\boldsymbol{\mu}_{\boldsymbol{v}_i} = \sum_{i=1}^{n} \boldsymbol{F}_{\boldsymbol{v}_{ij}} \tilde{v}_i$. Analogously, the "own forward component" can be defined as:

(7) $$\boldsymbol{\mu}_{v_i}^{own} = \boldsymbol{F}_{v_{ii}} \tilde{v}_i$$

and the "pure forward component" as:

(8) $$\boldsymbol{\mu}_{v_i}^{pure} = \sum_{j \neq i} \boldsymbol{F}_{v_{ij}} \tilde{v}_i$$

Similarly to above, the own forward component tells how variations in the production of a sector affect GHGs emissions in the sector itself, while the pure forward component must be interpreted as how variations in the production of a sector affect emissions from other sectors.

Own and backward components decomposition is complementary to the coefficient of variation. Sectors that show high own components are expected to show also high coefficient of variation. Moreover, high pure components depict the relevance of a sector because it makes others to pollute. Jointly with the coefficient of variation this is useful to depict if it makes one or few other sectors, or many of them to pollute. If a sector shows relevant both, own and pure components, the coefficient of variation omitting the main diagonal elements must be computed for avoiding biases produced by the own component.

2.3 Data

There is not an official input–output matrix for Uruguay. However, in the benchmark of an agreement between RED Mercosur – FAO for technical assistance to the Agriculture, Livestock and Fishing ministry, one input–output table for the year 2005 was constructed under direct supervision of the Central Bank of Uruguay (BCU), institution that publishes the national account information (Terra et al., 2009). There is a consensus on its validity, and it is the main reference for both public and private analysis. It is split in 56 activities at basic prices.

In reference to the greenhouse gas emissions, sectoral data is available. The *Third National Communication to the Conference of the Parties in the United Nations Framework Convention on Climate Change* (MVOTMA, 2010a) details the 2004 GHGs inventory. GHGs emissions accounts are going to be done following the Eurostat (2009) methodology. Secondary sources, like the reports of the National Energy and Nuclear Technology Direction (DNETN, 2008), which details the structure of net and used energy consumption for the year 2006 are used[5].

Table 1 depicts productive sectors GDP (in U$S millions) and total GHGs emissions (carbon dioxide, C_2O, methane, CH_4, nitrous oxide, N_2O, and total GHGs, CO_2e, all of them in ktons of CO_2-equivalent).

The Uruguayan productive structure in 2005 shows a high weight of services sectors (44 to 55), jointly with Building (43), as well as Cattle farming (6) and Meat production (11). For the analysis below it is important to note that on average 60% of productive inputs are primary inputs or imports, while 61% of the production leaves the productive system straight to final demand.

[5] A methodological annex detailing emissions sectoral allocation is available upon request.

Table 1: Productive Sectors, GDP and GHG emissions

Sector	BCU code	Name	GDP U$S :	%GDP	CO2 Ktons	%CO2	CH4 Ktons	%CH4	N2O Ktons	%N2O	CO2e Ktons	%CO2e
1	A.0111.1	Rice growing	4.309.645	0,6%	91,0	1,5%	743,7	4,0%	0,9	0,0%	835,6	2,3%
2	A.0111.9	Other cereals and crops	10.920.286	1,5%	112,9	1,9%	1,3	0,0%	1,6	0,0%	115,9	0,3%
3	A.0112.0	Vegetables and horticultural growing	2.651.709	0,4%	12,2	0,2%	0,0	0,0%	0,1	0,0%	12,3	0,0%
4	A.0113.0	Fruits growing	3.571.720	0,5%	19,3	0,3%	0,1	0,0%	0,2	0,0%	19,5	0,1%
5	A.0121.1	Raw milk and milk products prepared in premises	5.745.859	0,8%	65,4	1,1%	1328,3	7,1%	0,6	0,0%	1394,3	3,8%
6	A.0121.9	Cattle farming	24.104.733	3,4%	63,1	1,0%	15161,7	81,5%	12039	99,8%	27264,3	74,1%
7	A.0122.0	Other animal farming	2.750.275	0,4%	6,4	0,1%	18,3	0,1%	0,1	0,0%	24,8	0,1%
8	A.0200.0	Forestry and logging	3.383.589	0,5%	5,3	0,1%	0,0	0,0%	0,0	0,0%	5,4	0,0%
9	B.0500.0	Fishing	1.602.424	0,2%	169,3	2,8%	0,2	0,0%	1,1	0,0%	170,6	0,5%
10	C.TTTT.0	Mining and quarrying	1.571.233	0,2%	11,4	0,2%	0,0	0,0%	0,0	0,0%	11,5	0,0%
11	D.1511.0	Meat production	34.804.178	4,9%	114,4	1,9%	108,8	0,6%	0,0	0,0%	223,2	0,6%
12	D.1512.0	Fish processing and fish products	4.200.411	0,6%	0,0	0,0%	0,7	0,0%	0,0	0,0%	0,7	0,0%
13	D.1513.0	Fruit and vegetables processing and preserving	790.865	0,1%	0,0	0,0%	22,3	0,1%	0,0	0,0%	22,3	0,1%
14	D.1514.0	Manufacture of vegetable and animal oils and fats	718.571	0,1%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
15	D.1520.0	Dairy products	11.706.109	1,6%	134,8	2,2%	29,4	0,2%	0,0	0,0%	164,1	0,4%
16	D.1531.1	Rice mill products	5.547.101	0,8%	56,7	0,9%	0,0	0,0%	0,0	0,0%	56,7	0,2%
17	D.1531.9	Flour and other grain mill	1.814.534	0,3%	0,8	0,0%	0,0	0,0%	0,0	0,0%	0,8	0,0%
18	D.153R.0	Prepared animal feeds	1.584.977	0,2%	48,0	0,8%	0,0	0,0%	0,0	0,0%	48,0	0,1%
19	D.154R.0	Bakery and similar farinaceous products	6.746.418	0,9%	66,3	1,1%	0,1	0,0%	0,0	0,0%	66,4	0,2%
20	D.154S.0	Sugar and other food products	8.220.658	1,2%	41,4	0,7%	0,0	0,0%	0,0	0,0%	41,5	0,1%
21	D.1552.0	Wines	1.550.974	0,2%	35,2	0,6%	0,1	0,0%	0,0	0,0%	35,3	0,1%
22	D.1553.0	Manufacture of malt liquors and malt	2.385.078	0,3%	3,8	0,1%	0,1	0,0%	0,0	0,0%	3,9	0,0%
23	D.155S.0	Distilling, rectifying and blending of spirits;	3.685.600	0,5%	32,7	0,5%	0,2	0,0%	0,0	0,0%	32,9	0,1%
24	D.1600.0	Tobacco	1.501.578	0,2%	0,8	0,0%	0,0	0,0%	0,0	0,0%	0,8	0,0%
25	D.171T.0	Spinning, weaving and finishing of textiles	6.169.799	0,9%	69,9	1,1%	38,1	0,2%	0,0	0,0%	108,0	0,3%
26	D.17RT.0	Knitted and crocheted fabrics and articles	1.439.851	0,2%	12,5	0,2%	0,0	0,0%	0,0	0,0%	12,5	0,0%
27	D.18TT.0	Dressing and dyeing of fur; manufacture of articles of fur	6.686.382	0,9%	12,6	0,2%	0,0	0,0%	0,0	0,0%	12,6	0,0%
28	D.191T.0	Tanning and dressing and manufacture of leather	6.904.507	1,0%	23,0	0,4%	2,0	0,0%	0,0	0,0%	24,9	0,1%
29	D.1920.0	Footwear	924.413	0,1%	2,6	0,0%	0,0	0,0%	0,0	0,0%	2,6	0,0%
30	D.20TT.0	Wood products	4.348.518	0,6%	74,9	1,2%	0,0	0,0%	0,0	0,0%	75,0	0,2%
31	D.210T.0	Paper and paper products	3.639.192	0,5%	162,4	2,7%	0,1	0,0%	0,0	0,0%	162,5	0,4%
32	D.22TT.0	Publishing, printing and reproduction of recorded media	4.555.139	0,6%	16,9	0,3%	0,0	0,0%	0,0	0,0%	17,0	0,0%
33	D.23TT.0	Refined petroleum	25.054.421	3,5%	416,2	6,8%	3,9	0,0%	0,5	0,0%	420,6	1,1%
34	D.24RT.0	Pesticides and other agro-chemical products	2.867.357	0,4%	0,5	0,0%	0,0	0,0%	0,0	0,0%	0,5	0,0%
35	D.24ST.0	Pharmaceuticals	4.413.171	0,6%	5,3	0,1%	0,0	0,0%	0,0	0,0%	5,3	0,0%
36	D.24UT.0	Basic chemicals	8.873.082	1,2%	21,1	0,3%	0,1	0,0%	0,0	0,0%	21,2	0,1%
37	D.25TT.0	Rubber and plastics products	7.465.138	1,0%	1,5	0,0%	0,0	0,0%	0,0	0,0%	1,5	0,0%
38	D.26TT.0	Other non-metallic mineral products	5.040.907	0,7%	475,2	7,8%	0,3	0,0%	0,0	0,0%	475,6	1,3%
39	D.RRTT.0	Basic metals	15.129.577	2,1%	24,3	0,4%	0,1	0,0%	0,0	0,0%	24,3	0,1%
40	D.SSTT.0	Motor vehicles	4.189.354	0,6%	0,2	0,0%	0,0	0,0%	0,0	0,0%	0,2	0,0%
41	D.UUTT.0	Furniture	4.632.123	0,6%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
42	E.TTTT.0	Electricity, gas and water supply	20.424.593	2,9%	895,8	14,7%	16,2	0,1%	1,2	0,0%	913,2	2,5%
43	F.45TT.0	Building	60.352.312	8,5%	7,1	0,1%	0,0	0,0%	0,0	0,0%	7,1	0,0%
44	G.TTTT.0	Motor vehicles and oil retail trade	75.558.727	10,6%	14,8	0,2%	0,0	0,0%	0,0	0,0%	14,9	0,0%
45	H.55TT.0	Hotels and restaurants	21.161.561	3,0%	26,3	0,4%	0,0	0,0%	0,1	0,0%	26,4	0,1%
46	I.60TT.0	Land transport; transport via pipelines	23.362.416	3,3%	1261,2	20,7%	2,4	0,0%	17,5	0,1%	1281,1	3,5%
47	I.RRTT.0	Water and air transport	21.356.574	3,0%	1371,5	22,5%	0,4	0,0%	1,4	0,0%	1373,3	3,7%
48	I.64TT.0	Post and telecommunications	18.979.002	2,7%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
49	J.TTTT.0	Financial intermediation	30.345.866	4,3%	1,5	0,0%	0,0	0,0%	0,0	0,0%	1,5	0,0%
50	K.70TT.0	Real estate activities	52.815.274	7,4%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
51	K.RRTT.0	Renting of machinery and equipment	22.962.413	3,2%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
52	L.75TT.0	Public administration and defence; compulsory social security	30.212.439	4,2%	44,7	0,7%	0,0	0,0%	0,1	0,0%	44,8	0,1%
53	M.80TT.0	Education	17.617.332	2,5%	5,8	0,1%	0,0	0,0%	0,0	0,0%	5,9	0,0%
54	N.85TT.0	Health and social work	35.761.318	5,0%	16,9	0,3%	0,0	0,0%	0,1	0,0%	17,0	0,0%
55	O.TTTT.0	Sewage and refuse disposal	19.397.200	2,7%	40,9	0,7%	1132,1	6,1%	0,1	0,0%	1173,1	3,2%
56	P.9500.0	Private households with employed persons	4.690.947	0,7%	0,0	0,0%	0,0	0,0%	0,0	0,0%	0,0	0,0%
Total			**713.199.428**	**100%**	**6.097**	**100%**	**18.611**	**100%**	**12.065**	**100%**	**36.773**	**100%**
% Total emissions					**16,6%**		**50,6%**		**32,8%**		**100%**	

Source: own elaboration based in Terra et al. (2009), MVOTMA (2010a) and DNTEN (2008)

Methane emissions represent half of the total emissions of Uruguayan productive sectors, while nitrous oxide represents one third, and carbon dioxide the remaining 16%. Cattle farming sector (6) emits almost the total of methane and nitrogen oxide, while carbon dioxide emissions mainly come from Transport sectors (46 and 47) and Building (43).

3. Empirical results

Key sectors analysis is first developed for total GHG emissions, and then separate analyses for methane, carbon dioxide and nitrous oxide are done. Next three subsections depict key sectors analysis and linkages decomposition for the pollutants mentioned above. Linkages decomposition, relevant for policy guidelines, is only developed for the three specific pollutants. This is because policy guidelines are only relevant for specific gases, considering their weight in total emissions, while the analysis of key sectors in total GHGs emissions helps for constructing a general view of sectoral responsibilities on the problem as a whole. Also, because the first case seeks to give a global view, the relation between sectors' multipliers in scale terms is shown only for each gas specific case.

3.1 Total GHGs emissions

Expressions (3) and (4) have been computed in order to analyze sectors liability in relation to total GHGs emissions. Four key sectors are identified: sector 6, Cattle farming, and three services sectors, 46 and 47, two transport related services, and 55, Sewage and refuse disposal (Table 2).

Additionally, from a demand perspective only, six sectors are relevant through their backward linkages: sector 11, Meat production, 15, Dairy products, 45, Hotels and restaurants, 28, Tanning and dressing and manufacture of leather, 25, Spinning, weaving and finishing of textiles, and 16, Rice mill products. While sectors 11 and 25 take most of their inputs from sector 6, sectors 28 and 45 buy them from sector 11, indirectly demanding products to sector 6.

In reference to forward linkages, five sectors are identified as relevant: 42, Electricity, gas and water supply, 44, Motor vehicles and oil retail trade, 5, Raw milk and milk products prepared in premises, 33, Refined petroleum, and 49, Financial intermediation[6].

Table 2: CO_2e Linkages Uruguay 2005

	$\mu_v>\mu$					$\mu_v<\mu$				
	Sector	BL Ranking	CV^y	FL Ranking	CV^v	Sector	BL Ranking	CV^y	FL Ranking	CV^v
$\mu_y>\mu$	**6**	2	7,5	1	7,4	**11**	1	7,3	31	6,7
	55	6	6,9	8	7,0	**15**	3	6,1	27	6,5
	47	7	7,1	3	6,7	**45**	4	6,1	35	3,3
	46	9	6,8	6	6,2	**28**	5	7,0	46	6,8
						25	8	6,6	26	6,9
						16	10	6,3	40	4,8
$\mu_y<\mu$	**42**	11	7,0	7	6,2					
	44	12	3,0	4	5,2					
	5	15	7,2	5	7,1					
	33	21	7,1	2	3,7					
	49	43	2,8	9	4,9					
mean CV^y = 4.8										
mean CV^v = 5.2										

A significant part of the inputs of the key sectors are primary inputs and imports, but there is an important difference in the destination of their production. For sectors 46, 47, transport related, and 55, Sewage and refuse disposals, 60.8%, 67.2% and 85% of the output is respectively for final demand purposes, while the average is 61.5%. For sector 6, Cattle growing, only 12.5% of it has this destination, but 82.4% of its production goes as an input to sector 11, Meat production.

87.4% of sector 6 production is sold to other sectors and almost all of it goes to sector 11. But 85% of sector 11 production goes straight to final demand. Although sector 11 relies heavily on sector 6, it should be taken into account that sector 11 has very low forward linkages (it ranks 31st). The low forward linkages of sector 11 are a call to caution when giving so much importance to sector 6 forward linkages. A similar

[6] When taking the median as a classification reference, results changed a bit, but this information does not contribute much for the analysis. The median implies, by definition, that half of the sectors are considered as key, from a demand, supply, or both perspectives. Changing classification criteria to the median multiplier had two main effects in the results: it highlights the whole relevance of sectors that were already relevant from only one perspective, and it atomizes the number of sectors to be considered, by definition, when they can be really not relevant. In this way, this analysis could be useful as complementary when intervention in the most relevant sector is not feasible Results for any pollutant are not shown here, because of space convenience, but they are available upon request.

relation can be seen between sector 5 and 15. Finally, the impacts of production changes in sectors 33, 44, and 49 on the GHGs emissions of sector 6 make the forward linkages of those sectors to be relevant.

Comparing the results with a similar study on total GHGs emissions for Australia in 1995 (Lenzen, 2003), there are several differences. However, the greater sector decomposition of this study (134 sectors) makes comparisons difficult. Sector 47 is the only key sector for Uruguay that is also relevant for Australia, but only through its backward linkages. Moreover, sectors 11, 15 and 45 are relevant for both countries from a demand perspective, while sector 49 is relevant from a supply point of view. Also, while sector 42, the only key sector in reference to GHGs emissions in Australia, is relevant in Uruguay only through its forward linkages, sector 44 is relevant from a demand perspective in Australia but from a supply point of view in Uruguay. Finally, there are 6 sectors that are relevant in Uruguay, and not in Australia, while in 13 cases the inverse happens. The difference in the sectoral level of aggregation from both studies might be playing a role in this fact.

3.2 CH_4 emissions

Again, equations (3) and (4) have been computed to analyze key sectors in methane emissions. Similar results than previous section is shown by Table 3, except from the fact that sectors whose emissions come mainly from energy combustion do not appear.

Multipliers decomposition is made computing equations (5) to (8). Figure 1 depicts own and pure backward linkages. Those sectors identified as key backward linkages are driven entirely through their own component, while for those that were relevant only from a demand perspective, backward linkages are relevant because of their pure component. This result is not surprising, as we had seen in previous section. Sector 6, Cattle growing, is the main polluting sector (74.1% of total GHGs emissions), and most of their inputs (85%) come from primary inputs or imports. This makes its main effect to be the through the own component, because it does not pull other polluting sectors for supplying its inputs. Also, a small part of its production goes to final demand. This means that its product is almost all employed as input by other sectors, mainly by sectors 11, 15, 16, and 25, and also finally to sectors that take important part of their inputs from these, like sectors 28 and 45. This explains the relevance of the pure component of these sectors.

Table 3: CH_4 Linkages Uruguay 2005

	$\mu_v>\mu$					$\mu_v<\mu$				
	Sector	**BL Ranking**	**CV^y**	**FL Ranking**	**CV^v**	**Sector**	**BL Ranking**	**CV^y**	**FL Ranking**	**CV^v**
$\mu_y>\mu$	**6**	2	7,5	1	7,4	**11**	1	7,5	25	6,9
	55	4	7,5	3	7,3	**15**	3	7,3	27	5,2
						45	5	6,9	38	4,6
						28	6	7,4	48	5,7
						16	7	5	35	6,2
						25	8	7,1	24	6,9
$\mu_y<\mu$	**5**	9	7,5	2	7,4					
	1	10	4,7	6	7,2					
	44	12	5,0	5	5,8					
	49	31	5,6	7	5,7					
	33	43	5,5	4	5,3					

mean CV^y = 5.7
mean CV^v = 5.4

All of the sectors with relevant pure backward component do not show relevant own component (except sector 11, whose own component is a little bit over the mean). Also, all of them show high coefficient of variation value. This means that when these sectors' demand increases they pull only one or few sectors to pollute. Only sector 16 shows a coefficient of variation of its backward linkages a little bit over the mean, but still high ($CV_{16}^{y} = 5$).

A similar explanation depicts the forward methane emissions linkages (Figure 2). Again, key sectors forward linkages are mainly driven by the own component. As seen before, only 12.5% of sector 6 production goes to final demand, while most of its production is purchased by sector 11 (whose pure backward linkages were already analyzed). This, jointly with its great participation in total emission, explains the importance of the own component of its forward linkages. In this way, variations in sector 6 production increase pollution of the sector itself. This fact also explains the importance of sectors 1 and 5 own forward linkages. They emit 4% and 7.1% of total methane emissions, being the most important direct polluters after sector 6. Both sectors sell almost all their production inside the productive system, and are the main inputs of sectors 16 and 15 respectively, that do not emit methane. In this way, increasing their production increases their own emissions.

Figure 1: CH_4 – Backward linkages own and pure components

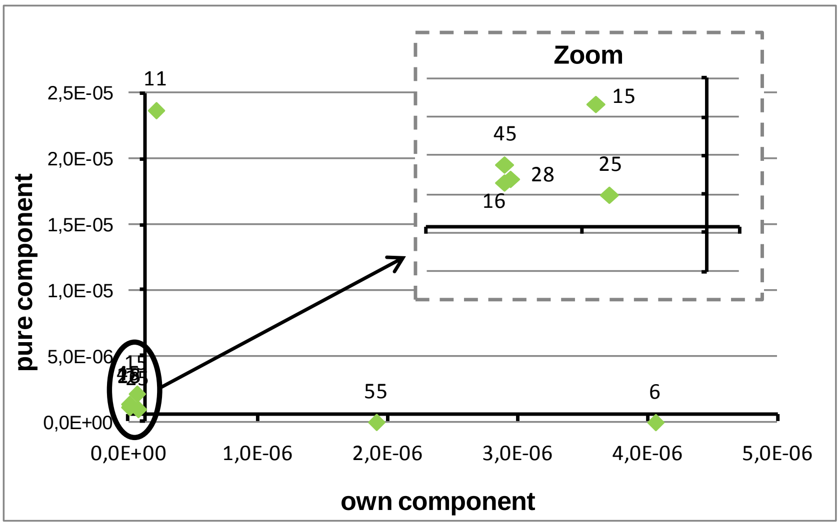
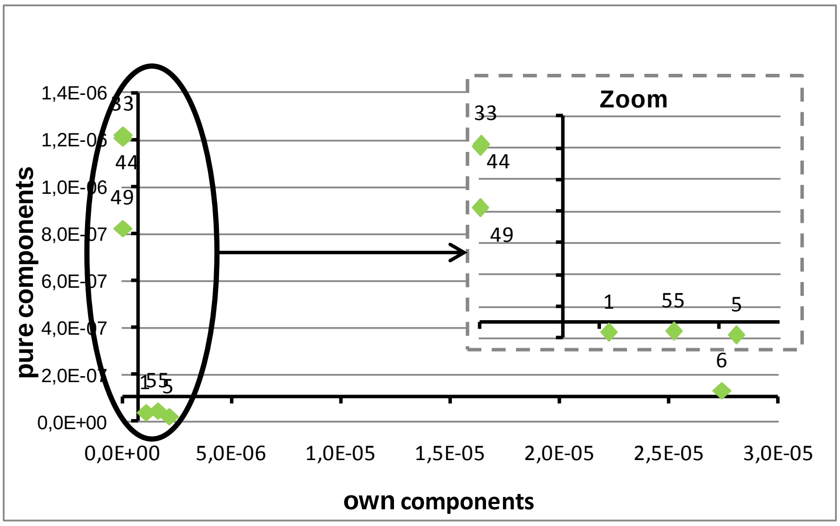


Figure 2: CH_4 - Forward linkages own and pure components



Sector 55 own forward linkages component is explained mainly because 75% of its production goes straight to final demand, while 4.5% is sold to itself. Sector 55 is a direct polluting sector, explaining the relevance of its own forward linkage.

In reference to those sectors that are relevant only through the supply perspective, sectors 44 and 49 forward linkages importance is explained through the pure component. Indirectly, both sectors production variations impact on sector 6 emissions, the main polluter. This makes both sectors pure forward linkages so important.

All the sectors with relevant pure forward linkages show high coefficients of variation (over five times the mean for each of them). This means that when their production increases, they pull one or few other sectors to pollute. This confirms the impact of these sectors expansion on sector 6 emissions.

3.3 CO_2 emissions

Carbon dioxide emissions structure is much different from total GHGs and methane emissions. These direct emissions are more distributed among sectors than previous ones, because they mainly come from fossil fuel combustion. Five sectors are identified as key through both backward and forward linkages: sectors 46 and 47, transport related, 44, Motor vehicles and oil retail trade, 42, Electricity, gas and water supply, and 33, Refined petroleum (Table 4).

Table 4: CO_2 Linkages Uruguay 2005

	$\mu_v>\mu$					$\mu_v<\mu$				
	Sector	BL Ranking	CV^y	FL Ranking	CV^v	Sector	BL Ranking	CV^y	FL Ranking	CV^v
$\mu_y>\mu$	47	1	7,3	1	7,2	43	4	5,2	22	1,8
	46	2	7	2	6,9	11	6	3,1	29	6,5
	42	3	7,1	4	7	15	7	4	18	7,2
	44	5	3,8	6	2,6	16	9	3,8	42	7,1
	33	8	7,2	3	4	45	10	2,1	33	4,1
						52	11	3,5	23	5,7
						12	12	6,3	51	4,4
						2	13	5,2	14	5,8
$\mu_y<\mu$	31	17	6,4	11	6,8					
	38	18	6,9	5	7,4					
	9	27	7,2	10	7,4					
	51	35	2,9	9	2,7					
	49	41	3,2	7	2,5					
	6	46	4,8	8	4,4					

mean CV^y = 4.4
mean CV^v = 5.1

Sectors 46 and 47 are the major carbon dioxide direct polluters (20.7% and 22.5% respectively), while their main input comes from other polluting sector (sector 33). Sector 33 directly emits 6.8% of total carbon dioxide emissions. 93% of its inputs are primary inputs or imports, while 61.5% of its production stays inside the productive system, and is required by all of the other sectors. Also, it is the main input for sectors that have relevant participation in CO_2 emission, like sector 1, Rice growing, 5, Raw milk and milk products prepared in premises, 9, Fishing, and 46 and 47, transport related sectors, while it is also used by sector 33 itself. Taking the above into account, sector 33 does not appear to pull other sectors so much when its demand increases.

Comparing results with similar studies for other countries is a delicate issue because of different sectoral aggregation level. Key sectors in reference to carbon dioxide emissions in Uruguay in 2005 are to high degree coincident with the ones of Spain in the year 2000 (Alcántara, 2007b), but not so much with the ones of Brazil in the year 2004 (Imori and Guilhoto, 2010). In comparison to the first case, almost all Spain's key sectors are also key sectors in Uruguay. Exceptional are the cases of sectors 38, Other non-metallic mineral products, 49, Financial intermediation, and 51, Renting of machinery and equipment, which are key in Spain, but only relevant from a supply perspective for Uruguay. Also, sector 47, Water and air transport, is key sector in Uruguay, while it is only relevant through its backward linkages in Spain. Moreover, all the remaining sectors from both perspectives in Spain are also relevant in Uruguay, but sectors 9, Fishing, and 31, Paper and paper products, are relevant through their forward linkages in Uruguay, but not in Spain.

Figure 3: CO_2 - Backward linkages own and pure components

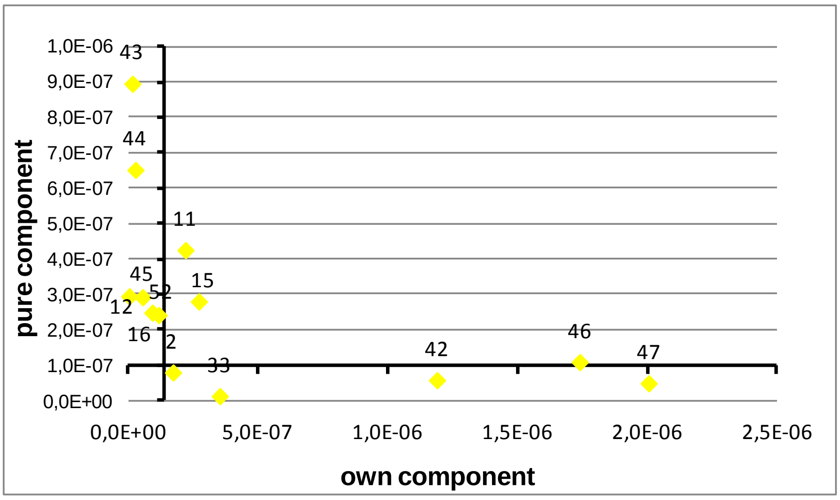
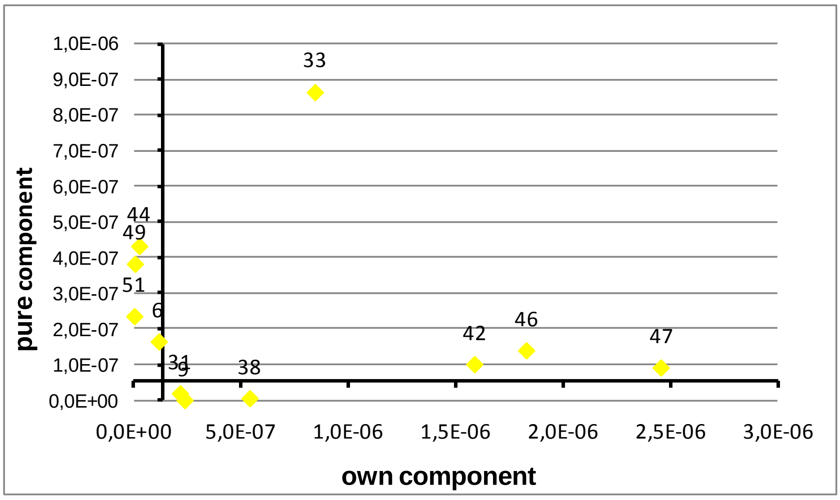


Figure 4: CO_2 - Forward linkages own and pure components



In reference to carbon dioxide emissions key sectors in Brazil, while transport related sectors 46 and 47 are relevant through both perspectives, sectors 11, 12, 15, and 16, Food industries, that are clustered together with other food industries sectors in Brazil, are key sectors in this country, but are only relevant from a demand perspective in Uruguay. This could be consequence of the higher degree of exports as final destination of this kind of products in Uruguay than in Brazil. More difficult is to compare other sectors, because of the high level of aggregation in Imori and Guilhoto (2010). But in general terms, metal-mechanics' industry appears to have a relevant role in carbon dioxide emissions structure in Brazil, that, because of the low weight of this sector in the Uruguay economy in 2005, does not play a relevant polluting role on it.

Decomposing carbon dioxide emissions through equations (5) to (8), on the one side, sectors 33, 42, 46 and 47 backward linkages are driven mainly by their own component (Figure 3). Those sectors are almost all the ones that pollute through their own productive processes. In this way, the importance of their own component can be explained by the weight of primary inputs or imports in their total inputs, or the weight of the purchases of their own sector inputs. This makes the variation in their production to produce variations in their own emissions.

On the other side, sector 33 is driven both through its own and pure component, while sector 44 backward linkages are driven mainly by its pure component. Taking into account the coefficient of variation, sector 33 shows a high value in reference to its backward linkages[7]. This means that when its demand increases it makes to pollute one or few other sectors. In particular, in addition to the emissions that it produces as consequence of the purchases it makes to itself, it makes sector 46, Land transport and transport via pipelines, to pollute. Also sector 44 backward linkages are driven by its pure component. So, increasing sector 44 final demand makes other sectors to pollute, but also this is not concentrated in only one or few sectors. This is because the retail oil trade is not polluting itself, but it demand inputs from polluting sectors, like sector 33, 42, 46 and 47.

While those sectors with relevant pure backward linkages component show a similar weight than the previously considered of primary inputs and imports on their total inputs, they are not direct polluters. In this way, this component is explained because of their input demand from polluting sectors. An expansion of their demand makes other sectors to increase their emissions. Finally, sectors 11 and 15, which show low levels of emissions in their productive processes, show relevant both, own and pure components.

In reference to carbon dioxide forward linkages decomposition, Figure 4 shows sector 33 is driven both by its own and pure components, while sectors 9, 38, 42, 46 and 47 forward linkages are driven mainly by their own component. Those sectors are almost all the ones that pollute during their productive process. In this way, the importance of their own component can be explained by the weight of final demand on their total sales, or the weight of the sales to their own sector, what makes variation in their production to cause variations in their own emissions. Sector 33 is important both, because a significant part of its production goes to other sectors, while increasing it also pulls its own pollution.

Sectors 44, 49 and 51 forward linkages decomposition is mainly explained by their pure forward component. This is because increases in their production also increase the emissions of sectors 42, 33, 46, and 47. The forward linkages of sector 5 are driven mainly by the own component, but their magnitude are very low. Sector 6 shows relevant pure forward components, and its impact is also very low.

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[7] The coefficients of variation of sector 33 when not taking into account the main diagonal are $CV_{33}^{y} = 4.6$ and $CV_{33}^{v} = 3.5$

When taking into account the coefficient of variation, all those sectors with relevant pure forward linkages show low values. This means that when they expand their production, the pollution that they induce on other sectors is not concentrated in only one or few sectors.

3.4 N_2O emissions

Nitrous oxide direct emissions are produced almost all by sector 6, Cattle farming, being the only key sector in reference to these emissions. Those sectors relevant from a demand perspective are those that demand inputs to sector 6 (sectors 11, 25 and 28), or to sectors that are supplied by them (sector 45). Finally, from a supply perspective, only sectors 33, 44 and 49 are relevant.

Table 5: N_2O Linkages Uruguay 2005

	$\mu_v>\mu$					$\mu_v<\mu$				
	Sector	BL Ranking	CV^y	FL Ranking	CV^v	Sector	BL Ranking	CV^y	FL Ranking	CV^v
$\mu_y>\mu$	6	2	7,5	1	7,5	11	1	7,5	41	7,4
						45	3	7,5	32	7,3
						28	4	7,5	50	7,4
						25	5	7,5	40	7,4
$\mu_y<\mu$	44	8	7,3	2	7,5					
	49	33	7,1	4	7,5					
	33	46	4,6	3	7,4					
mean CV^y = 6.7										
mean CV^v = 7.2										

Figure 5: N_2O - Backward linkages own and pure components

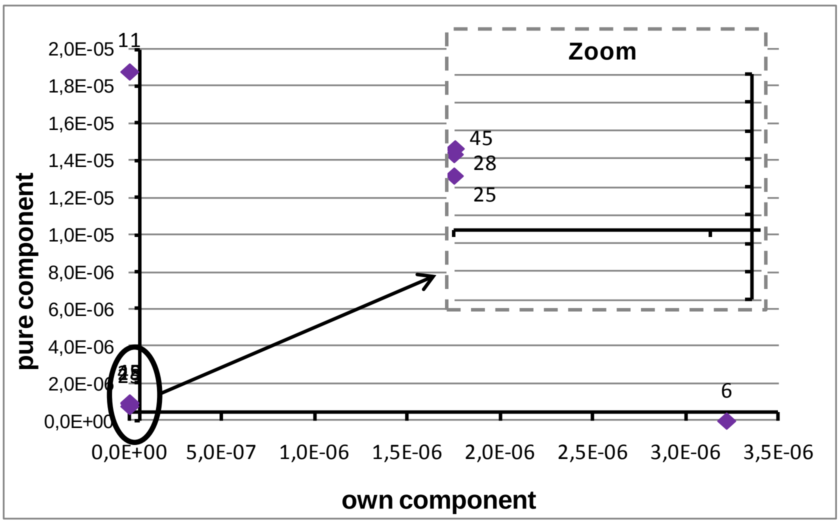
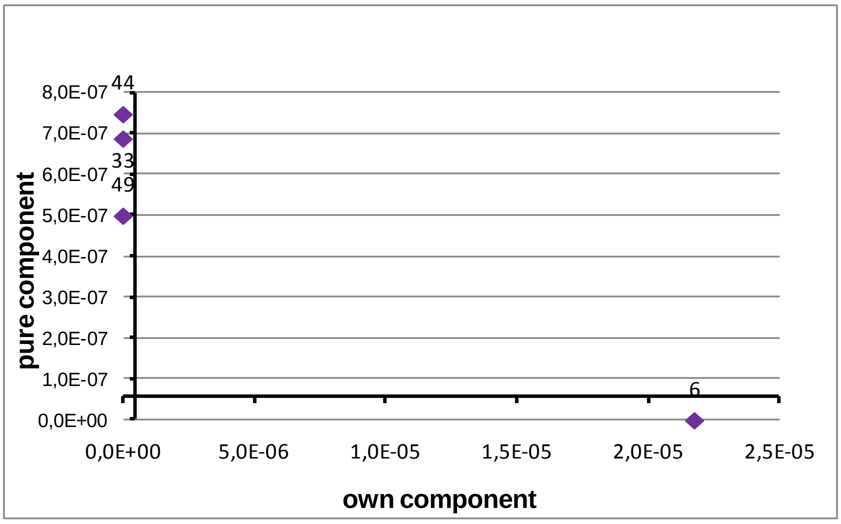


Figure 6: N_2O - Forward linkages own and pure components



Sector 6 is relevant because of its own component as it is responsible of almost all its direct emissions, any increase in its demand or production implies variations in emissions generated by its own production process. On the other hand, all the sectors relevant from a demand perspective are important through their pure backward linkages, as consequence, as mentioned above, that they demand inputs to sector 6 (or to sectors that are supplied by it) (Figure 5).

Finally, those sectors relevant from a supply perspective are also relevant through their pure forward linkages, because variations in their production impacts on sector 6 emissions (Figure 6).

All the sectors with relevant pure backward or forward components shows high coefficient of variation. This means that increases in their final demand or production makes only one or few other sectors to pollute (that is consistent with the result we already saw, because they push and pull sector 6 to pollute).

4. Policy implications

Policy measures are not going to be of the same nature if a sector is relevant due to its own or pure linkages. Also, policy measures are not going to be the same if their target is only one sector, or more than one. Table 6 surveys the relation between linkages and policy measures.

Following Alcántara et al. (2010), policies looking for GHGs reduction should be encouraged over those sectors with either a high own backward, own forward or pure forward component. Targeting these would reduce pollution either from the sector itself or from other sectors (in the case of pure forward components).

When only one sector with high own component is involved, technological and practices improvements would be efficient diminishing this sector emissions. These type of measures would not be effective in sectors with a high pure component. In sectors with high pure forward component, policies should aim to reduce emissions in sectors related with their supply. When more than one sector are involved in the polluting process, specific policies to one sector are not enough, and cross sectoral policies should be encouraged.

Table 6: Linkages and Policy measures

If sectors show HIGH		Policies
Own backward or forward components	→	**Sectoral measures directly reduce resource use or environmental degradation: Technological improvement and best practices**
Pure forward components, and many sectors involved	→	**Inter-sectoral policies**
Pure backward	→	**Sectoral policies are not effective, demand policies are needed**

Finally, sectoral measures to reduce emissions would not be effective in sectors with a high pure backward component because these sectors are not directly responsible for GHGs emissions. In this case, other sectors demand products from these sectors with a high own backward component and, thus, these other sectors are responsible for these GHGs emissions. In this case, demand measures should be adopted.

Policy analysis is only relevant in reference to each specific gas, not for total GHGs emissions, as different gases are generated by different processes. Next three subsections discuss policy measures in reference to methane, carbon dioxide and nitrous oxide emissions in the Uruguayan economy, given its productive structure in 2005.

4.1 Sectoral policy discussion on methane emissions

First of all, it is worth to note that direct emissions of sector 6, Cattle farming, amount to 81.5% of total methane emissions, while direct emissions of Sectors 1, Rice growing, 5, Raw milk and milk products prepared in premises, and 55, Sewage and refuse disposal, are 4%, 7.1% and 6.1% respectively (the direct emissions of these four sectors amount for 98.7% of total methane emissions; see Table 1).

As stated in previous sections, these sectors show high own backward and/or forward linkages. So, targeting these four sectors would be effective for diminishing methane emissions. Also, sector 11, Meat production, which is not a main direct polluter, shows high own backward components. However, they are small in comparison to the multipliers of previously mentioned sectors, as well as its pure backward effects. In this way, sectoral policy measures on sector 11 would be less effective in controlling methane emissions. Finally, sectors 33, Refined petroleum, 44, Motor vehicles and oil retail trade, and 49, Financial intermediation show relevant pure forward linkages. Policy efficiency can be complemented taking measures through their supply to the polluting sectors.

Policy action priority lines for GHGs mitigation, defined at the National Climate Change Response Plan (NCCRP) (MVOTMA, 2010b), straight target sectors 6 and 55 (Table A.1 in Annex I). Also, while energy efficiency to diminish direct emissions is identified as a priority, it is very broad. Following our analysis, improvements in sector 11 would help to greater mitigate methane emissions from this source. Also, an interesting point of the analysis above is the availability of complementary measures through sectors 44 and 49.

4.2 Sectoral policy discussion on carbon dioxide emissions

It is worth to note that sectors 33, Refined petroleum, 38, Other non-metallic mineral products, 42, Electricity, gas and water supply, 46, Land transport and transport via pipelines, and 47, Water and air transport, emit through their own productive processes

6.8%, 7.8%, 14.7%, 20.7% and 22.5% of total carbon dioxide emissions respectively (their direct emissions amount to 72.5% of total CO_2 emissions; see Table 1).

Technical improvement and better practices measures should focus on sectors 33, 42, 46, and 47, which show relevant own forward and backward, and pure forward linkages, and the high magnitude of their multipliers makes them the most relevant in terms of policy making. Also relevant are sectors 2, 11 and 15, which show high own backward linkages, and sectors 9, 31 and 38, with a relevant own forward component. Finally, policy measures can again be complemented taking measures through sectors 44 and 49 supply to the polluting sectors.

The NCCRP identifies transport sector as a line of action for GHGs mitigation. Also, improving energy efficiency is going to have great impact if actions are taken in sectors 2, 11, and 15. Also, sector 33 emissions reduction would have a great impact in total emissions. In this sense, diversifying the energy matrix is an important task targeted at the NCCRP, only if it helps to diminish sector 33 emissions. Also energy efficiency improvements would be relevant in sectors 9, 31 and 38, that show relevant own forward linkages. Other complementary measures can be taken on those sectors that present relevant pure forward linkages.

4.3 Sectoral policy discussion on nitrous oxide emissions

Key sectors analysis for this pollutant is partially coincident with methane emissions one. In this way, section 5.1 discussion is also relevant for nitrous oxide emissions, without considering sector 55, which is not relevant in this case.

5. Conclusions and lines to follow

The present paper shows key sectors in GHGs emission of the Uruguayan economy in 2005. Sectoral linkages have been decomposed in terms of own and pure components. This analysis is relevant because policy design for mitigating emissions are going to be different if a sector pollutes through its own production process, or because it makes other sectors to pollute. As a general result, all those key polluting sectors for the different gases considered are relevant because of their own emissions, except for sector 44, Motor vehicles and oil retail trade, that is relevant because of its pure, both backward and forward linkages. Also, when considering its coefficient of variation, this sector responsibility spreads among several sectors.

Next, the best policy channels for controlling and reducing GHGs emissions have been identified. The NCCRP policy lines of action target mitigation of emissions from primary sector, energy consumption, transport and waste. The present paper complements it, allowing to determine in which sectors the lines of actions defined are going to be more effective, and to measure its impact. This is particularly relevant in reference to energy efficiency improvements.

In prospective, technical and cost viability of policy interventions should be included into the policy making decision process. In which sectors to focus on, and what kind of policy mechanisms to apply is a first step for mitigating the GHGs emissions of the Uruguayan economic system.

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8. Annex

Table A.1 Lines of action for GHGs emission mitigation		
Primary Sectors	Cattle farming and dairy products	Best practices in dairy and cattle closures manure management for reducing methane emissions
		Improving animal diets with prairie planting
		Soil carbon sequestration through productivity of pastures promotion
	Agriculture	Soil carbon sequestration through reduced tillage methods, direct seeding and proper selection of crop sequences or pastures rotations
		Promoting innovative management of irrigation and fertilization practices for reducing methane emissions from flooded rice cultivation
		Encourage fossil fuels substitution by agricultural and agroindustrial waste biomass
		Increase fossil energy and nitrogen fertilizer use efficiency
	Forests and Forestry	Encourage efficient forest plantations as carbon sink development
		Encourage use of wood residues from forests and forest industry as alternative energy sources
		Promote native forests protection and enhance their protection through a more efficient application of existing legislation
Energy	Energy matrix diversification	Support specific initiatives of the Strategic Energy Development guidelines for 2015 goals
	Energy efficiency	Ensure continuity of energy efficiency policies developed in the Energy Efficiency Project of the DNE-Uruguay
	Emissions reduction	Identify GHGs mitigation measures for the energy sector, and consider it application in different industries.
		Define and apply energy efficiency standards and norms, in reference to building materials thermal properties and building characteristics
		Residential and services lighting systems efficiency improvement
Transport	Energy consumption reduction	Define plans and policies that would help reduce energy consumption, diversifying the energy matrix and defining actions to improve transport energy use efficiency
		Improve public transport systems for passengers and cargo transport efficiency through alternative transportation and energy sources
		Promote more energy efficient transportation and to continue replacing fossil fuels with biofuels
		Evaluate the potential of the Uruguay river navigation development
Waste	Emissions reduction	New urban biogas capture landfill for reducing methane emissions from decomposition of solid waste
		Promote industrial processes wastewater treatment plants anaerobic lagoons replacement by anaerobic intensive processes
CDM		Public strategy design for taking advantage of opportunities for supporting sustainable developing that can exist

Source: MVOTMA (2010a) and MVOTMA (2010b)

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