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Departament d'Economia Aplicada
Edifici B
Campus de Bellaterra
08193 Bellaterra

Telèfon: 93 581 1680
Fax: 93 581 2292
E-mail: d.econ.aplicada@uab.es
http://www.uab.cat/departament/economia-aplicada/

Identification of relevant sectors in CO_2 emissions in Ecuador through input–output analysis

Edwin Buenaño[a], Emilio Padilla[b]; and Vicent Alcántara[b]

[a] School of Physical and Mathematics Sciences, Pontificia Universidad Católica del Ecuador, Quito, Ecuador

[b] Department of Applied Economics, Universidad Autónoma de Barcelona, Campus de Bellaterra, 08193, Cerdanyola del Vallès, Spain.

E-mails: evbuenano@puce.edu.ec; emilio.padilla@uab.es; vicent.alcantara@uab.es

Abstract

We analyse the relationship between the Ecuadorian economy and environmental pollution from an input–output approach, thereby identifying the key sectors in CO_2 emissions and establishing a typology of them for the year 2013. The methodology used determines the economic activities that have greater responsibility in the generation of emissions, due to their own production or their interrelation with other activities. In addition, this influence is broken down into two types of effects (own and pure), which allow for a better perspective of the influence that the key sectors exert on the rest of the activities. The results show that, in addition to activities traditionally considered as polluting (transport, electricity and oil derivatives), there are others, such as commerce, construction, telecommunications and government administrative services, which are also highly responsible for the generation of emissions in the entire productive system.

Keywords: CO_2 emissions, input–output analysis, key sectors.

1. Introduction

The Paris Agreement, signed by consensus among the 195 member countries of the United Nations Framework Convention on Climate Change, built upon previous commitments, such as the 1992 Rio Summit, the Kyoto Protocol, the Conference of the Parties (COP 17) and so on. These agreements highlight the international concern regarding climate change

and the growing political relevance of the objective of sustainable development, which requires a balance between the environmental, social and economic dimensions.

In addition to being part of several of these global agreements, Ecuador has developed the concept of "good living" ("*buen vivir*") as a roadmap for its growth and development (SENPLADES, 2013). Under this concept, the environmental dimension plays a fundamental role in achieving these objectives. However, achieving an adequate balance between the economic, environmental and social dimensions can be very complex.

We propose the use of the environmentally extended input–output (IO) approach to determine the relationship between economic structure and material flows. This tool provides information that allows us to understand the existing relationships between productive structures and the effects that their interrelation generate on the environment.

The initial model of Leontief (1936) has been developed and used in the study of multiple issues related to economics, such as labour, trade, energy and environmental issues. As Hoekstra (2010) notes, between 1970 and the beginning of the 90s, the research related to the Leontief model focused mainly on the energy issue. Later, the analyses extended to the environment increased considerably.

Regarding the determination of key sectors, the first proposals were those of Rasmussen (1956), who defined the coefficients of "dispersion and absorption", through the direct and indirect relationships between the different sectors. The proposal of Chenery and Watanabe (1958) presented their "direct multipliers" of activity, which quantify only direct effects through the matrix of technical coefficients. Hirschman (1958) used the ideas of the aforementioned authors and raised the notion of linkages and the importance of certain branches due to the potential effect they exert on other activities. He also discussed the importance that different types of backward and forward linkages between sectors can have on the economy. Later, Hazari (1970), in an empirical work on the Indian economy and using the Rasmussen indexes, raised the idea of weighing the sectors according to the relative weight they have in the economy. In this way, he introduced the idea of "weighted multipliers". There were also questions regarding how to estimate forward linkages. Thus, Jones (1976) suggested that the Ghosh supply model (1958) should be used instead of the Leontief inverse as in Rasmussen's original proposal.

In summary, the information contained in an IO matrix allows the detection of the "key sectors" of an economy based on the set of sectoral interdependencies, distinguishing two types of linkages: forward and backward linkages. The former arise when a sector produces goods and services that will be used by others as intermediate inputs, generating a "push" effect. In contrast, backward linkages allow us to quantify the capacity of a sector to induce the development of others, by using the goods produced by them as intermediate inputs, causing a "pull" effect. The key sectors will be those that have both strong backward and forward linkages.

In general, the methodology of key sectors can be applied to any vector of sectoral coefficients that we wish to investigate. In the environmental field, Alcántara (1995) analysed the forward and backward linkages of SOx emissions for Catalonia (Spain). Lenzen (1998) investigated greenhouse gases and primary energy consumption through an analysis of Australian domestic production and imports. Duarte et al. (2002) applied this methodology for the use of water in Andalusia (Spain).

The empirical application carried out in this work follows the line of studies such as that of Alcántara (2007), who related the structure of the Spanish economy to CO_2 emissions, using supply and demand multipliers, determining the key sectors in the emissions, Alcántara and Padilla (2006), who identified "key" productive sectors analysing the impact that an increase in the value added of the different productive sectors would have on total CO_2 emissions, and identifying the productive sectors responsible for the increase in emissions when the income of the economy increases, and Imori and Guilhoto (2007), who used this methodology to analyse the key sectors in the relationship between economic performance and CO_2 emissions during 2002 in Brazil. Likewise, Jodar (2011) used the IO tools to determine the key sectors in the Swiss economy and performed a decomposition between pure and own effects in the forward and backward linkages. Piaggio (2013) and Piaggio et al. (2014) also applied IO tools to identify the key sectors in greenhouse gas emissions for Uruguay. Regarding the Ecuadorian case, although the use of the IO approach in conjunction with the methodology of key sectors has been used in several investigations (see Gachet, 2005; Artola, 2009; Fernández, 2007), it has not been applied to analyse environmental issues.

To carry out this study, it was necessary to estimate a vector of CO_2 emissions by economic activity. We employed the method proposed by Alcántara and Roca (1995) and Alcántara et al. (2008), which established IO energy relations by the type of energy and economic activity, allowing us to estimate a vector of emissions attributable to each activity. The data obtained is one of the important contributions of this research to the generation of environmental information in Ecuador, since we provide a CO_2 emissions vector disaggregated by economic activity.

The study is structured as follows. Section 2 develops the methodology used. Section 3 makes a brief description of the data. Section 4 presents the main findings and their discussion. Finally, the main conclusions are presented in Section 5.

2. Methodology for the analysis of key sectors

Our starting point is the system of equations of the Leontief model $\mathbf{Ax} + \mathbf{y} = \mathbf{x}$, where $\mathbf{A}$ is the matrix of coefficients or technical requirements, $\mathbf{x}$ is the vector of total domestic production and $\mathbf{y}$ is the vector of final demand, whose solution is given by $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$, which expresses the endogenous variable $\mathbf{x}$ as a linear combination of the exogenous variable $\mathbf{y}$, being $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{B}$ the Leontief inverse matrix[1]. The methodology to determine the key sectors in the emission of CO_2 described below follows the proposal by Alcántara (2007).

We define $\mathbf{c}_{\mathrm{nx1}}$ as a vector of relative CO_2 emission coefficients, the result of dividing the emissions of each economic activity (in tons of CO_2) by the sectoral production (in millions of dollars), such that:

(1) $\mathbf{c}'\mathbf{x} = \mathbf{e}$

where $\mathbf{e}$ is a scalar that measures total CO_2 emissions. Replacing $\mathbf{x}$ with its equivalent of the Leontief model, we have:

(2) $\mathbf{e}^{\mathbf{d}}_{\mathrm{nx1}} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$

[1] The matrices are represented by uppercase letters, while the vectors are represented by lowercase letters. Both vectors and matrices are indicated with bold. The symbol "^" represents the diagonalisation of a vector.

where $\hat{\mathbf{c}}$ is the diagonalised matrix of emission coefficients and $\mathbf{e}^{\mathbf{d}}_{\mathrm{nx1}}$ is the vector of sectoral direct emission.
We define the following matrix:

(3) $\mathbf{F}_{\mathbf{y}_{\mathrm{nxn}}} = \hat{\mathbf{c}}(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}$

where $\mathbf{F}_{\mathbf{y}}$ is a linear operator that converts any increase in final demand into emission increases. Moreover, if matrix $\mathbf{F}_{\mathbf{y}}$ is pre-multiplied by $\mathbf{u}'$ (1xn), a unit row vector, we have:

(4) $\mathbf{f}'_{\mathbf{y}_{\mathrm{1xn}}} = \mathbf{u}'\mathbf{F}$

where $\mathbf{f}'_{\mathbf{y}}$ is a total (direct and indirect) unit emission vector generated per unit of final demand and represents the multiplier effect of the emissions driven by the expansion of the final demand of the different economic activities. This vector expresses what is known as backward linkages, in this case in the emissions, due to the expansion of the final demand.
In the same way, it is possible to establish a vector of total (direct and indirect) sectoral emissions, as given by the following expression:

(5) $\mathbf{e}^{\mathbf{t}}_{\mathrm{1xn}} = \mathbf{c}'(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\hat{\mathbf{y}}$

However, $\mathbf{f}'_{\mathbf{y}}$ is not a scaled vector, which means that these are only potential multipliers. For this reason, it is necessary to define a new vector that introduces the demand weight of the different sectors.
From the final demand vector, a distribution vector $\tilde{\mathbf{y}}$ is defined, such that $\sum_i \tilde{y} = 1$. In this way, the backward linkage is redefined as:

(6) $\boldsymbol{\mu}'_{\mathbf{y}_{\mathrm{1xn}}} = \mathbf{c}'(\mathbf{I} - \mathbf{A})^{-\mathbf{1}}\hat{\tilde{\mathbf{y}}}$

where, $\boldsymbol{\mu}_{\mathbf{y}}^{'}$ is a vector of weighted emission multipliers, in response to an expansion of demand.

Regarding the supply multipliers, Jones (1976) proposed to use the Ghosh model (1958) to measure forward linkages. Several authors argue that the Leontief inverse matrix is not adequate to measure (direct or total) forward linkages (Cella, 1984; Dietzenbacher, 1992; 1997; Oosterhaven, 1996; Dietzenbacher and Van der Linden, 1997; Robles and Sanjuán, 2005, 2007; Miller and Blair, 2009)[2].

Therefore, following the Ghosh model, we have:

(7) $\mathbf{x}^{'} = \mathbf{v}'(\mathbf{I} - \mathbf{D})^{-\mathbf{1}}$

where $(\mathbf{I} - \mathbf{D})^{-\mathbf{1}}$ is the Ghosh inverse matrix, in which **D** is the matrix of distribution coefficients, **x** is the vector of production and **v** the vector of primary inputs used for production. Relating it to the emission vector, we have:

(8) $\mathbf{e}^{\mathbf{t}}_{\mathrm{nxn}} = \hat{\mathbf{v}}'[\mathbf{I} - \mathbf{D}]^{-\mathbf{1}}\mathbf{c}$

Therefore, we can define a matrix $\mathbf{F_v}$:

(9) $\mathbf{F}_{\mathbf{v}_{\mathrm{nxn}}} = (\mathbf{I} - \mathbf{D})^{-\mathbf{1}}\hat{\mathbf{c}}$

Such that $\mathbf{F_v}$ is a linear operator, similar to the operator $\mathbf{F_y}$ found in the demand model, which transforms increments of primary inputs into emissions.

Post-multiplying $\mathbf{F_v}$ by a unit vector, we have:

(10) $\mathbf{f}_{\mathbf{v}_{\mathrm{nx1}}} = \mathbf{F_v}\mathbf{u}$

[2] The discussion of this point is extensive and can be reviewed in Lenzen (2003). As noted by Oosterhaven (1988), the Leontief and Ghosh models can be used together only as descriptive tools for forward linkage analysis and key sectors, since it is essential for impact analysis that matrix **A** be constant.

where $\mathbf{f_v}$ is a vector of total (direct and indirect) unit emission generated by the expansion of primary inputs that expresses what is known as forward linkages, in this case in the emission[3].

As in the demand case, biases may occur that must be corrected by defining a new distribution vector of primary inputs, in this case $\tilde{\mathbf{v}}$, such that $\sum_i \tilde{v} = 1$. In this way, the supply multiplier is redefined as:

$$(11)\ \boldsymbol{\mu}_{\mathbf{v}_{nx1}} = \hat{\tilde{\mathbf{v}}}(\mathbf{I} - \mathbf{D})^{-\mathbf{1}}\mathbf{c}$$

where $\boldsymbol{\mu}_{\mathbf{v}_{nx1}}$ is a vector of weighted emission multipliers in response to an expansion of primary inputs.

$$(12)\ \mu = \frac{\boldsymbol{\mu}_{\mathbf{y}}'\mathbf{u}}{n} = \frac{\boldsymbol{\mu}_{\mathbf{v}}'\mathbf{u}}{n}$$

where n is the number of sectors considered.

However, Rasmussen (1956) indicated that the most important key sectors will be those that extend their effects to the rest of the sectors in greater quantity, so he proposes to use the coefficient of variation to know the level of dispersion of each activity in the effects. That is, if the *j-th* activity affects all activities uniformly or is concentrated in a few. Thus, for the demand case, the coefficient would be:

$$(13)\ CV_j^y = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(a_{ij} - \frac{1}{n}\sum_{i=1}^{n} a_{ij})^2}}{\frac{1}{n}\sum_{i=1}^{n} a_{ij}}$$

On the supply side, the influence on the *i-th* industry would be calculated as follows:

$$(14)\ CV_i^v = \frac{\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(d_{ij} - \frac{1}{n}\sum_{j=1}^{n} d_{ij})^2}}{\frac{1}{n}\sum_{j=1}^{n} d_{ij}}$$

[3] The terms backward linkage, demand multipliers or pull effect, will be used interchangeably throughout the text; as well as the terms forward linkage, supply multipliers or push effect.

Therefore, the key sectors will be those with high backward and forward linkages ($\frac{\boldsymbol{\mu}_{\mathbf{y}}'\mathbf{u}}{n}, \frac{\boldsymbol{\mu}_{\mathbf{v}}'\mathbf{u}}{n}$), respectively, and, in addition, low coefficients of variation (CV_j^y, CV_i^v), respectively. That is to say, the key sectors require, in relative terms, more inputs than the rest of the activities in the face of an increase in final demand or in primary inputs. In addition, their purchases and/or sales are not concentrated, but are distributed equally among the rest of the activities.

In addition, distinguishing between the pollution generated by an activity due to its own production process and the pollution indirectly generated through the production processes of other activities is very useful for the design of policies focused on pollution mitigation. Alcántara et al. (2010) propose decomposing the backward and forward linkages into two components called "pure" and "own", for which we must make use of the matrixes of the supply and demand weighted multipliers.

In the case of demand, the decomposition of backward linkages into their own and pure components is given by:

(15) $\boldsymbol{\mu}_{\mathbf{y_j}}^{\mathbf{own}} = \mathbf{F}_{\mathbf{y_{jj}}}\tilde{\mathbf{y}}$

(16) $\boldsymbol{\mu}_{\mathbf{y_j}}^{\mathbf{pure}} = \sum_{\mathbf{i}\neq\mathbf{j}} \mathbf{F}_{\mathbf{y_{ij}}}\tilde{\mathbf{y}}$

Similarly, in the case of supply, the decomposition of forward linkages into their own and pure components is given by:

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

(18) $\boldsymbol{\mu}_{\mathbf{v_i}}^{\mathbf{pure}} = \sum_{\mathbf{j}\neq\mathbf{i}} \mathbf{F}_{\mathbf{y_{ij}}}\tilde{\mathbf{v}}$

The advantage of these expressions is that such decomposition would be useful for the design of mitigation policies. As discussed by Alcántara et al. (2010) and Piaggio et al. (2014), environmental mitigation measures will be more effective in economic activities

that have a high own backward, own forward or pure forward component, since they will allow the mitigation of the contamination of the activity itself or of others that also pollute. In this sense, when it comes to an activity with a high own component, the measures adopted should focus on technological improvements or better practices, since they would be effective in reducing pollution. When dealing with activities with a high pure forward component, policies should be implemented to reduce the emissions associated with the activities where the production of these is destined, and policies can also be designed to help to reduce the pollution process of the input that such activities require. In addition, when more than one activity is involved in the process, specific policies are not enough, but intersectoral policies must be used. Finally, in the case of activities with a high pure backward component they demand products from directly polluting activities; therefore, measures that reduce their demand, as well as technological measures or best practices that reduce their demand for polluting inputs, can be effective.

Considering the above, the classification of the activities according to their relevance can be established according to Table 1.

Table 1. Classification of activities.

Key sector classification	$\mu_{v,i}/\mu > 1$	$\mu_{v,i}/\mu < 1$
$\mu_{y,j}/\mu > 1$	Key sectors	Demand drivers
$\mu_{y,j}/\mu < 1$	Supply drivers	Rest of sectors
Backward linkage classification	$\mu_{y_j}^{pure} > \overline{\mu_{y_j}^{pure}}$	$\mu_{y_j}^{pure} < \overline{\mu_{y_j}^{pure}}$
$\mu_{y_j}^{own} > \overline{\mu_{y_j}^{own}}$	Relevant sectors in pure and own backward linkage components	Relevant sectors only in own backward linkage component
$\mu_{y_j}^{own} < \overline{\mu_{y_j}^{own}}$	Relevant sectors only in pure backward linkage component	Rest of sectors
Forward linkage classification	$\mu_{v_i}^{pure} > \overline{\mu_{v_i}^{pure}}$	$\mu_{v_i}^{pure} > \overline{\mu_{v_i}^{pure}}$
$\mu_{v_i}^{own} > \overline{\mu_{v_i}^{own}}$	Relevant sectors in pure and own forward linkage components	Relevant sectors only in own forward linkage component
$\mu_{v_i}^{own} > \overline{\mu_{v_i}^{own}}$	Relevant sectors only in pure forward linkage component	Rest of sectors

Source: Adapted from Jodar (2011).

3. Data description

For the development of this research, the IO tables published by the Central Bank of Ecuador (BCE) were used for 2013 (BCE, 2016). The figures are in current terms and use the year 2007 as the base year. The official publication is a 71×71 square matrix, disaggregated into 16 activities belonging to the primary sector, 36 to the manufacturing sector and 18 to the service sector. Regarding CO_2 emissions, in the absence of disaggregated figures at the activity level, we made our own estimate by using. We used data on energy balances published by the IEA (2016), data on energy balances published by the Coordinating Ministry of Strategic Sectors of Ecuador (MICSE), and conversion factors from IPCC (2008), whose main results and methodology are presented in the Annex.

4. Main results and discussion

4.1 Direct and total effects

Based on expression (5), the direct and total emissions were calculated for the 71 economic activities of the IO matrix in 2013, which generated a total of 42,019 Kton of CO_2. Table 2 shows the ten activities with the greatest weight in CO_2 emissions (the Annex contains the information for all activities). These ten activities are responsible for 78.1% of direct emissions (32,815 Kton of CO_2). However, if only direct emissions were considered, we would be ignoring that a large part of the emissions of the different productive sectors ultimately serve to facilitate the production of other sectors. That is, the production of an activity generally requires the production of goods or services that are supplied by other activities. This generates a pull effect on the emissions of an activity that, on occasions, may be higher than the emissions generated directly (Alcántara and Padilla, 2009). In this sense, the total (direct and indirect) emissions of the analysed group represent 67.3% of the total emissions generated by productive sectors. Therefore, if the total emissions are lower than the direct emissions, this means that some of these activities generate more direct

emissions because they must satisfy the demand for inputs from other activities (see, for example, the case of transport).

Table 2. Ten activities with the greatest weight in direct and total CO_2 emissions (Kton).

Cod.	Actividad	Direct Emissions	%	Total Emissions	%
58	Transport and storage services	9,189	21.9%	4,986	11.9%
38	Refined petroleum oils and other products	7,399	17.6%	3,632	8.6%
51	Electricity	6,773	16.1%	4,257	10.1%
12	Crude oil and natural gas	2,200	5.2%	3,926	9.3%
44	Cement, articles of concrete and stone	1,870	4.5%	- 36	-0.1%
64	Services provided to companies and production	1,275	3.0%	148	0.4%
54	Trade services	1,261	3.0%	2,437	5.8%
53	Construction and construction works	1,231	2.9%	5,916	14.1%
65	Administrative services of the government and for the community in general	856	2.0%	1,752	4.2%
60	Telecommunications, transmission and information services	762	1.8%	1,280	3.0%
	Total	**32,815**	**78.1%**	**28,299**	**67.3%**

Source: prepared by the authors based on Table A.2 information (in the Annex) from BCE (2016) data.

Table 2 shows the different sectoral responsibilities in relation to emission; for example, the activity (58) "Transport and storage services" represents 21.9% of direct emissions of the entire productive system, while its relative importance in total (direct and indirect) emissions decreases to 11.9%. Even though it is a very influential activity in terms of generating CO_2 emissions, its emissions fall to approximately half when its total emissions are analysed. Transport is a clear example that there are activities that produce to a large extent to satisfy the demand from the rest of productive activities. The CO_2 emissions of this sector are due, in a large part, to its provision of services to other sectors. Similarly, other activities with a behaviour similar to that described are: (38) "Refined petroleum oils and other products", (51) "Electricity", (44) "Cement, articles of concrete and stone" and (64) "Services rendered to companies and production".

In contrast, an opposite example is the activity (54) "Trade services", which represents 3% of the emissions generated directly, but according to their total emissions, its weight rises to 5.8%. This is because other activities have to increase their production to meet the demand for inputs required by this activity. That is, by itself, trade is not a relevant factor in the direct generation of emissions, but its relevance is strengthened when analysing its productive linkages. Other activities with a similar behaviour are (53) "Construction and construction work", (65) "Administrative services of the government and for the

community in general", and (60) "Telecommunications, transmission and information services".

4.2 Key sectors

For the analysis of key sectors, we used the weighted multipliers that would generate an expansion of the demand or of the primary inputs, calculated on the basis of the expressions (6) and (11), respectively. In addition, their coefficients of variation were calculated, based on expressions (13) and (14). Table 3 presents the classification of the activities that were relevant according to the methodology used.

Table 3. Classification of economic activities in key sectors and sectors that are relevant from a demand- or supply-side perspective.

Cod.	Activity	μj/μ	cvj	μi/μ	cvi	Classification
58	Transport and storage services	8.4	2.3	12.6	4.3	key sector
38	Refined petroleum oils and other products	6.1	3.3	11.0	6.2	key sector
12	Crude oil and natural gas	6.6	5.0	6.2	3.4	key sector
51	Electricity	7.2	5.2	5.8	5.9	key sector
54	Trade services	4.1	1.4	4.8	3.5	key sector
53	Construction and construction works	10.0	6.4	1.5	2.5	key sector
65	Administrative services of the government and for the community in general	3.0	8.4	1.1	3.8	key sector
60	Telecommunications, transmission and information services	2.2	5.7	1.1	5.1	key sector
64	Services provided to companies and production	0.2	1.4	6.8	5.3	relevant from supply
44	Cement, articles of concrete and stone	-0.1	7.6	1.9	5.5	relevant from supply
40	Other chemical products	0.8	5.8	1.1	6.7	relevant from supply
13	Services related to oil and natural gas	0.0	6.9	1.1	6.4	relevant from supply
5	Oilseeds and industrialised products	0.1	3.2	1.1	7.1	relevant from supply
61	Financial intermediation services	0.4	3.6	1.0	5.5	relevant from supply
63	Real estate services	1.6	5.0	0.8	5.5	relevant from demand
57	Restaurant services	1.5	7.6	0.7	3.8	relevant from demand
70	Association services; leisure; cultural and sports	1.2	7.4	0.6	5.7	relevant from demand
16	Meat, meat products and by-products	1.5	6.9	0.2	4.1	relevant from demand
17	Elaborated shrimp	1.8	8.2	0.1	4.4	relevant from demand
	Means		6.6		6.4	

Source: prepared by the authors based on Table A.2 information (in the Annex) from BCE (2016) data.

The group of greatest interest consists of eight activities, which have the highest demand (backward linkage) and supply (forward linkage) multipliers. In other words, these activities would be the ones that generate the greatest push and pull effects on the rest of the economy in the generation of CO_2 emissions. This group is made up of the following activities: (58) "Transportation and storage services", (38) "Refined petroleum oils and other products", (51) "Electricity", (12) "Crude oil and natural gas", (54) "Trade services", (53) "Construction and construction works", (65) "Administrative services of the

government and for the community in general" and (60) "Telecommunications, transmission and information services". The eight activities are responsible for 70.6% of direct emissions and 67.1% of total emissions (see Table A.1 in the Annex).

Five activities have higher than average multipliers, but only on the demand side (backward linkages); and, another group, made up of six activities, has higher than average multipliers, but only on the supply side (forward linkages).

It should be noted that, in order to verify if similar results are obtained in the determination of forward linkages using the Leontief inverse instead of the Ghosh inverse, the calculations presented in Table A.4 were made. The result was that none of the key sectors are affected by this calculation. There are two activities that are classified as influential from the supply side, regardless of the methodology used; and, obviously, the influential activities on the demand side do not suffer any alteration. Therefore, 10 of the 14 activities classified as relevant do not undergo any change in their classification and only four would change their typology depending on the calculation method used[4]. What is exposed in this point, plus the justifications of the methodological section, justify continuing the rest of the analysis based on the estimates with the Ghosh inverse.

In summary, the data show that, of the 71 existing activities in the productive system, 19 can be classified as the most influential in CO_2 emissions.

It is worth noting that the activities belonging to the group of key sectors that have high weighted backward linkage multipliers ($^{\mu}y,j/_{\mu}$) and weighted forward linkage ($^{\mu}y,i/_{\mu}$) are the same as those that are significantly more distant above the average, with the exception of the activities (65) "Administrative services of the government and for the community in general" and (60) "Telecommunications, transmission and information services", which have the lowest weighted multipliers, that is, close to the unit; and the activity (53), which has a very high weighted linkage backward multiplier, but a weighted forward linkage multiplier close to unity.

[4] The relevant activities from the supply-side that do change are: (13) "Services related to oil and natural gas", (5) "Oilseeds and industrialized products" and (61) "Financial intermediation services" are classified as relevant from the supply-side only when the Ghosh inverse is used. In contrast, the activity (10) "Fish and other aquatic products (except shrimp)" is classified as relevant only when the Leontief inverse is used.

Regarding the behaviour of the coefficients of variation of the group of key sectors, it can be seen that, in general, they have coefficients lower than the average, which means that their purchases and sales are deconcentrated. Therefore, the impulses that are carried out on these activities, from the demand or from the primary inputs, would increase the CO_2 emissions of several economic activities that are linked to them.

In the case of the group of activities that are relevant from the demand perspective, their weighted multipliers are close to unity, with the highest multiplier of the activity (17) "Elaborated shrimp" (1.8 times the average). In addition, in most cases there are high coefficients of variation significantly higher than the average, which represents a concentration in the purchases made by these activities.

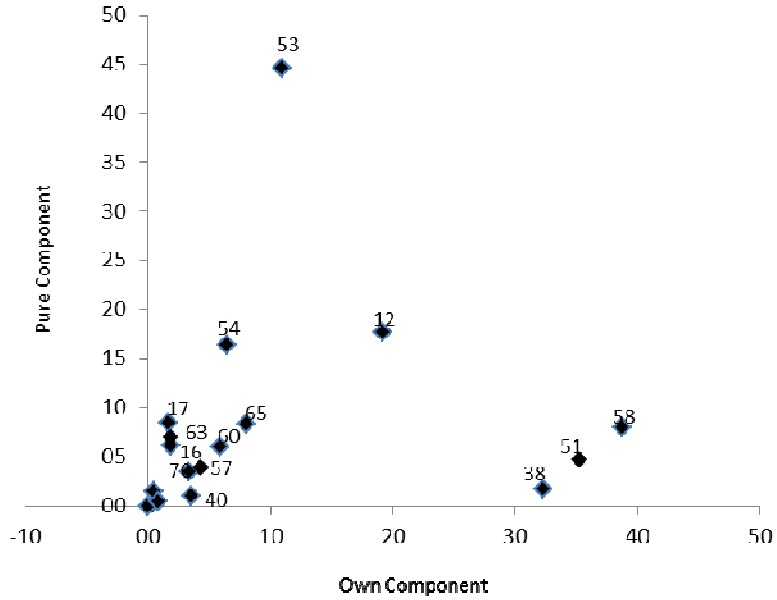
On the supply side, the weighted multiplier of the activity (64) "Services provided to companies and production" stands out, which is significantly different from the average. However, the other activities of this group have multipliers very close to unity. Regarding the coefficients of variation, the pattern is less clear than in the other cases, since they are around the average.

4.3 **Own and pure components of the relevant activities in the emission of CO_2**

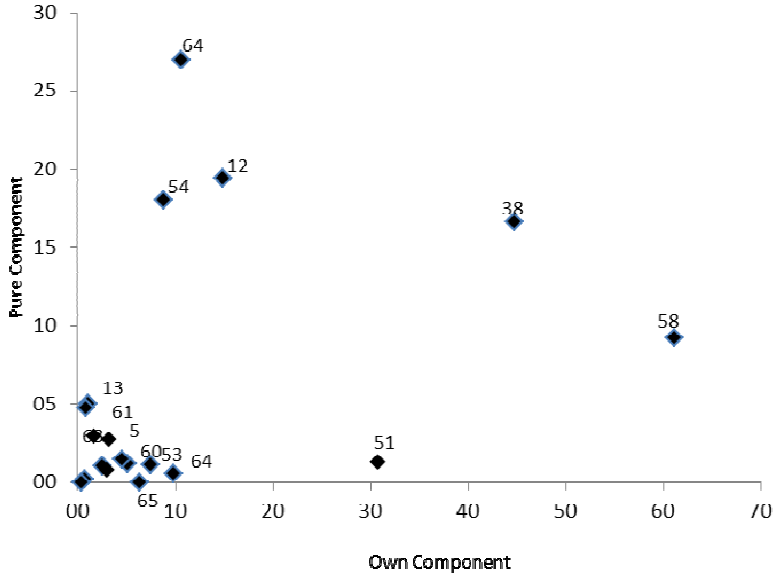
With the aim of providing inputs for decision making in environmental policy, we add to the above information the calculations obtained through expressions (15) to (18), which allow us to determine the pure and own components of the backward and forward linkages. This information is presented for the 19 relevant economic activities, since these are the activities that have a greater weight in the generation of CO_2 emissions.

Figure 1. Pure and own components of backward and forward linkages.

Panel a. backward linkages



Panel b. forward linkages



Source: prepared by the authors based on Table A.5 (in the Annex) with BCE (2016) data.

A first group of activities is composed of (58) "Transportation and storage services", (51) "Electricity" and (38) "Refined petroleum oils and other products", which jointly generate 55.6% of the total emissions. They are characterised by having both high demand and

supply weighted multipliers. These activities are linked to the entire productive system, so their coefficients of variation are low. In addition, activities (51) and (38) are the sources of energy from which the entire productive system is provided, while activity (58) is the mechanism that serves as a link for the entire economy.

Due to the above, these are highly influential activities in the generation of CO_2 emissions, both because of their own characteristics and because of the supply and demand interrelations they maintain with the rest of the economy. The intervention with direct measures on these activities will be the one that generates the greatest impacts. These measures include both technological improvements and the promotion of best practices. For example, the use of refined petroleum with better technology or the generation of electricity from clean sources would have a strong impact on mitigation.

In contrast, the activity (12) "Crude oil and natural gas" also has high demand and supply multipliers, but in this case both the pure and the own components of the backward and forward linkages are high. That is, it is an activity that generates CO_2 emissions both in its own production and its interrelation with other activities (pull and push effects). It has a strong link with the previously described group of activities: transport, electricity and refined petroleum, but especially with the latter. Therefore, policy measures should include both direct and indirect measures on the sectors that provide and demand inputs from this activity and that have the strongest backward and forward linkages.

The activity (54) "Trade services" is characterised by having high supply and demand multipliers, but mainly because its pure backward and forward linkages components are greater than its own components. In this sense, it is not an activity that generates high pollution by itself but is characterised by doing it indirectly. It is also characterised by having low coefficients of variation, since its interrelations are deconcentrated throughout the productive system. The first policy measure is to begin to consider this sector within the relevant polluting activities, since it is not usually considered among the relevant polluting activities. In this way, a deeper analysis of its supply and demand interrelations would allow to properly design measures of labelling, clean production, or energy efficiency on other activities, to achieve a positive impact in the reduction of CO_2 emissions. Previous analyses for other economies, such as the Spanish (Alcántara and Padilla, 2009) or the

Uruguayan (Piaggio et al., 2015), also agree on the important role of various service activities in indirect emissions.

The activity (53) “Construction and construction works” is the activity with the highest economic growth in recent years, largely due to the increase in public and private works, as a result of expansive demand policies. The analysis shows that it has one of the highest backward linkages multipliers along with a high coefficient of variation. Likewise, its high pure component stands out, as well as its indirect emissions. This is due to the interrelation that exists with the activity (44) “Cement, articles of concrete and stone”, which is a relevant supplier of inputs (and the fifth activity in the generation of direct emissions). This means that the emissions of activity (44) are transferred to the construction activity; and to a lesser extent, to the activities (58) “Transportation and storage services” and (51) “Electricity”. Therefore, policies that improve the productive process of the manufacture of cement or alternative building materials more friendly to the environment will have a positive impact on construction emissions.

The activities (65) “Administrative services of the government and for the community in general” and (60) “Telecommunications, transmission and information services” stand out because they are not usually considered important activities in the generation of CO_2 emissions and therefore are not included in the design of mitigation policies. However, as shown in this study, these are activities that stand out for their forward and backward linkages. Although their relevance must be nuanced against other activities that generate greater contamination, it is worth highlighting some characteristics. On the demand side, both have similar pure and own backward linkage components, while on the supply side, its own component is much higher. As for their coefficients of variation, they are higher than in the sectors previously analysed, particularly on the demand side and especially for the activity (65); that is, their interrelation with the rest of activities is more concentrated. In this case, energy efficiency or energy saving policies could be useful, due to their strong connection with electricity and transport activity. Therefore, measures that promote the use of clean energy and the saving of energy from fossil fuels would be useful to reduce CO_2 emissions.

The activities that are relevant only from the demand side are: (63) “Real estate services”, (57) “Restaurant services”, (70) “Association services; leisure; cultural and sports”, (16)

"Meat, meat products and by-products" and (17) "Elaborated shrimp". All of these are characterised by having close to average multipliers. Likewise, their pure backward linkage component is, in general, greater than their own component. The policies to adopt should be focused on the activities that are suppliers of their inputs, as the increase in demand will pull polluting sectors to increase these emissions. In contrast, direct policies would not have the desired effect (unless they had a direct impact on their final demand), since neither their direct emissions nor their own backward linkages are significant.

Finally, there are the relevant activities from the supply-side perspective: (64) "Services provided to companies and production", (44) "Cement, articles of concrete and stone", (40) "Other chemical products", (13) "Services related to oil and natural gas", (5) "Oilseeds and industrialised products" and (61) "Financial intermediation services". Among them, the activity (64) stands out, since it presents the strongest forward linkage of the whole group (the other relevant sectors from the supply-side have multipliers close to the average). Its pure forward linkage is higher than its own component; therefore, it is also an activity that is indirectly induced to emit CO_2 because its sales are destined to other activities that are highly polluting, such as transportation, cement, electricity, or refined petroleum, among others. For this reason, the policies focused on the sectors where their production is destined would allow a reduction of the emissions of this activity. Another activity with similar characteristics is (61) "Financial intermediation services", for which, as pointed out by Piaggio et al. (2014), an efficient policy would be the creation of credit access incentives, as well as preferential interest rates aimed at financing non-polluting activities. Finally, the activities (44) "Cement, articles of concrete and stone" and (40) "Other chemical products", are activities on which direct policies, of best practices and technology, should be implemented since their own component is high. While the activities (13) "Services related to oil and natural gas" and (5) "Oilseeds and industrialised products" require mixed measures, which mitigate their own emissions and those of activities to which they provide inputs.

4.4 Classification of the sectors based on their indirect component

We broke down the total emissions of each activity into the pure and own effects (both for the backward and the forward linkage components). Remembering that the own effect is that which is generated due to the productive process of an activity and that the pure effect is generated indirectly through the productive processes of other activities; if the interest falls on analysing exclusively those activities that generate the greatest impacts due to their indirect effects (forward or backward), the activities considered key or relevant from a supply or demand side, could be modified. That is, isolating the pure effect of the pollution generated by each activity could serve to think about policies related to multisectoral impacts.

Table 4. Classification of sectors based on their indirect component.

		Decomposition in own and pure effects				
		Backward Linkage		Fordward Linkage		
	Traditional typology	Relevant effect own (>1)	Relevant effect pure (>1)	Relevant effect own (>1)	Relevant effect pure (>1)	Tipology indirect effect
Cod.	μj/μ	μj/μ (propio)	μj/μ (puro)	μi/μ (propio)	μi/μ (puro)	
12	key sector	6.75	6.52	4.18	9.76	indirect key sector
54	key sector	2.28	6.05	2.47	9.07	indirect key sector
58	key sector	13.61	2.97	17.11	4.63	indirect key sector
63	relevant from demand	0.64	2.60	0.45	1.50	indirect key sector
53	key sector	3.84	16.47	2.10	0.54	indirect from demand
17	relevant from demand	0.60	3.12	0.12	0.02	indirect from demand
65	key sector	2.82	3.10	1.78	0.00	indirect from demand
60	key sector	2.09	2.25	1.29	0.74	indirect from demand
16	relevant from demand	0.67	2.28	0.21	0.10	indirect from demand
51	key sector	12.36	1.76	8.60	0.66	indirect from demand
70	relevant from demand	1.18	1.27	0.71	0.52	indirect from demand
57	relevant from demand	1.51	1.47	0.83	0.41	indirect from demand
64	relevant from supply	0.30	0.19	2.97	13.57	indirect from supply
38	key sector	11.35	0.66	12.54	8.35	indirect from supply
61	relevant from supply	0.16	0.56	0.22	2.40	indirect from supply
13	relevant from supply	0.00	0.00	0.29	2.54	indirect from supply
5	relevant from supply	0.11	0.06	0.88	1.39	indirect from supply
40	relevant from supply	1.25	0.39	1.43	0.59	none
44	relevant from supply	-0.09	-0.03	2.76	0.29	none

Source: prepared by the authors based on Table A.5 (in the Annex) with BCE (2016) data.

Table 4 shows that, of the eight sectors that were considered key, three would remain in that category, motivated exclusively by their indirect impacts. These sectors correspond to the activities: (12) "Crude oil and natural gas", (54) "Trade services", and (58) "Transportation and storage services". In addition, the activity (63) "Real estate services", which was previously relevant only from the demand perspective, would now become a key

sector due to its indirect impacts. In contrast, of the remaining five activities that were considered as key sectors, four are still relevant, but only because of their indirect demand effects, these are: (17) “Elaborated shrimp”, (65) “Administrative services of the government and for the community in general”, (60) “Telecommunications, transmission and information services” and (51) “Electricity”; while the activity (38) “Refined petroleum oils and other products” becomes a relevant activity because of its indirect effects but on the supply side.

The sectors that were previously considered relevant (by demand or supply perspectives) still have this category, but here exclusively because of their indirect effects; with the exception of two activities: (40) “Other chemical products” and (44) “Cement, articles of concrete and stone”.

The above is useful to demonstrate the importance that the sectors selected by the methodology as relevant in CO_2 emissions have a strong indirect component, which is why policies such as those proposed to mitigate environmental pollution on these activities would have useful chain effects to mitigate pollution.

Likewise, the importance of commercial activity, and real estate activity, within the Ecuadorian productive structure as regards CO_2 emissions, are highlighted. It is evident how the economic growth of recent years has influenced a set of activities that apparently are not linked to environmental pollution, but whose interrelationships are decisive in the generation of CO_2 emissions.

Finally, as can be seen in Table 4, there are important differences in the structure of each of these activities with respect to their influence on emissions, which is why a combination of direct, indirect and demand policies would generate the best results.

5. Conclusions

The first contribution of this research lies in the construction of a vector of CO_2 emissions for the Ecuadorian economy disaggregated by economic activity, prepared for the year 2013. For this, we constructed a matrix of primary and secondary energy consumption and linked it to the IO matrix of 2013. In this way, it is possible to estimate the energy consumption by activity, which, in turn, allows us to quantify the CO_2 emissions generated

by each economic activity. The generation of this data is useful for multiple analyses of environmental issues.

Through the analysis of key sectors, we determined that, of the 71 economic activities, 19 are relevant in CO_2 emissions. According to the typology used, eight are classified as key sectors, five are relevant from the demand- and six from the supply-side perspective. Together, all of them would be responsible for 85.1% of direct emissions and 79.8% of total emissions.

The activities classified as key sectors are: (58) “Transportation and storage services”, (38) “Refined petroleum and other products oils”, (51) “Electricity”, (12) “Crude oil and natural gas”, (54) “Trade services”, (53) “Construction and construction work”, (65) “Administrative services of the government and for the community in general” and (60) “Telecommunications, transmission and information services”. These are characterised by strong forward and backward linkages with the rest of the productive structure, which is why they are influential in the generation of CO_2 emissions. Therefore, from a public policy perspective, it would be useful to analyse the most appropriate forms of intervention on these activities, since it would be where the measures would potentially be more effective.

Activities such as (58) “Transportation and storage services”, (38) “Refined petroleum oils and other products”, (51) “Electricity” or (12) “Crude oil and natural gas”, have a high responsibility in the generation of CO_2 emissions. In addition, a disaggregation in their pure and own components has allowed us to define more clearly the appropriate environmental policy tools that could be used in these activities to reduce their direct and indirect contamination.

The methodology used also allows finding highly influential activities that are generally outside the radar of policy makers; in particular those related to the services sector, such as (54) “Trade services”, (65) “Administrative services of the government and for the community in general” and (60) “Telecommunications, transmission and information services”. Their direct control is important, but it is also relevant to look at the activities with which they have stronger interrelations, both backwards and forwards.

Another group of relevant activities is distinguished by its strong linkages, but only backwards or forwards. The findings show that it would not be effective to apply the same

policies to one or another group of activities, but that it depends on the interrelationships that exist with the rest of the economy.

Several of the policy plans and strategic guidelines established in the "National Plan for Good Living" ("*Plan Nacional del Buen Vivir*") (SENPLADES, 2013) contemplate measures whose objectives align with those suggested in the study. Among them, the change in the energy matrix for the generation of hydroelectric power stands out, which will have an important impact on the reduction of CO_2 emissions, both for those directly related to the electricity sector, as well as those indirect for its interrelation with the rest of the economy. Other policies, such as the modernisation of the vehicle fleet, the improvement in the production of petroleum derivatives or energy saving campaigns, should also be deepened since they would be effective in reducing emissions from some sectors that appear as key.

The results obtained expand the range of possibilities and activities on which to deepen the analysis for a more efficient development of public policy on environmental issues.

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Annexes

Table A.1. Estimation of CO_2 emissions by economic activity for Ecuador for 2013.

Cod.	Activity	Emission ktCO2	%
1	Banana, coffee and cocoa	174.88	0.42%
2	Cereals	59.84	0.14%
3	Flowers and buds	75.70	0.18%
4	Tubers, Vegetables, melons and fruits	118.15	0.28%
5	Oilseeds and industrialised products	395.19	0.94%
6	Services related to agriculture	142.42	0.34%
7	Live animals and animal products	504.35	1.20%
8	Forestry products	45.91	0.11%
9	Live or fresh shrimp and shrimp larvae	563.08	1.34%
10	Fish and other aquatic products (except shrimp)	609.50	1.45%
11	Aquaculture products (except shrimp)	38.77	0.09%
12	Crude oil and natural gas	2,200.01	5.24%
13	Services related to oil and natural gas	135.68	0.32%
14	Metallic minerals	106.20	0.25%
15	No-metallic minerals	117.42	0.28%
16	Meat, meat products and by-products	241.55	0.57%
17	Elaborated shrimp	186.94	0.44%
18	Fish and other processed aquatic products	87.06	0.21%
19	Prepared and preserved fish and other aquatic species	142.37	0.34%
20	Crude and refined oils	55.00	0.13%
21	Processed dairy products	66.87	0.16%
22	Grain mill products	29.40	0.07%
23	Bakery products	50.00	0.12%
24	Noodles, macaroni and other similar farinaceous products	39.00	0.09%
25	Sugar, brown sugar and molasses	128.50	0.31%
26	Elaborated cocoa, chocolate and confectionery products	31.36	0.07%
27	Animal food	11.75	0.03%
28	Processed coffee products	42.34	0.10%
29	Various food products	106.85	0.25%
30	Alcoholic beverages	81.18	0.19%
31	Non-alcoholic beverages	44.63	0.11%
32	Elaborate tobacco	0.46	0.00%
33	Threads, spinning, weaving and confection	129.24	0.31%
34	Clothing	35.35	0.08%
35	Leather, leather products and footwear	24.68	0.06%
36	Products of treated wood, cork and other materials	443.31	1.06%
37	Pulp, paper and cardboard, editorial products and others	157.72	0.38%
38	Refined petroleum oils and other products	7,398.86	17.61%
39	Basic chemical products, fertilizers and primary plastics	29.93	0.07%
40	Other chemical products	691.19	1.64%
41	Rubber products	13.51	0.03%
42	Plastic products	163.98	0.39%
43	Glass, ceramics and refractories	396.87	0.94%

cont..

Cod.	Activity	Emission ktCO2	%
44	Cement, articles of concrete and stone	1,869.93	4.45%
45	Common metals	117.42	0.28%
46	Processed metal products	189.66	0.45%
47	Machinery, equipment and electrical appliances	192.93	0.46%
48	Transportation equipment	76.54	0.18%
49	Furniture	49.03	0.12%
50	Other manufactured products	129.63	0.31%
51	Electricity	6,772.62	16.12%
52	Water, sanitation and gas services (oil exc)	56.03	0.13%
53	Construction and construction w orks	1,230.87	2.93%
54	Trade services	1,260.50	3.00%
55	Repair and maintenance services of motor vehicles and motorcycles	18.86	0.04%
56	Accommodation services	188.01	0.45%
57	Restaurant services	517.21	1.23%
58	Transport and storage services	9,188.83	21.87%
59	Postal and courier services	39.26	0.09%
60	Telecommunications, transmission and information services	761.75	1.81%
61	Financial intermediation services	127.42	0.30%
62	Insurance services and pension funds	10.54	0.03%
63	Real estate services	231.89	0.55%
64	Services provided to companies and production	1,275.17	3.03%
65	Administrative services of the government and for the community in general	855.99	2.04%
66	Private education services	19.68	0.05%
67	Public education services	100.86	0.24%
68	Social and health services	22.44	0.05%
69	Non-market social and health services	182.83	0.44%
70	Association services; leisure; cultural and sports	416.33	0.99%
71	Domestic service	-	0.00%
	TOTAL	**42,019.24**	**100%**

Source: prepared by the authors based on IEA (2016) energy balances, SUT tables (BCE, 2016) and IPCC (2008) guidelines.

Note: We used the methodology of Alcántara and Roca (1995) and Alcántara et al. (2008) for the estimation of the vector of CO_2 emissions. This required to estimate a vector of primary energy consumption disaggregated in the 71 activities of the IO matrix. We used data on energy balances published by the IEA (2016), data on energy balances published by the Coordinating Ministry of Strategic Sectors of Ecuador (MICSE), conversion factors from IPCC (2008), final energy consumption data disaggregated in supply and use tables (SUT) and information of the IO matrix provided by BCE (2016).

Table A.2. Direct and total CO_2 emissions by economic activity.

Código	Activity	Direct emission	%	Total emission	%
58	Transport and storage services	9189	21.9%	4986	11.9%
38	Refined petroleum oils and other products	7399	17.6%	3632	8.6%
51	Electricity	6773	16.1%	4257	10.1%
12	Crude oil and natural gas	2200	5.2%	3926	9.3%
44	Cement, articles of concrete and stone	1870	4.5%	-36	-0.1%
64	Services provided to companies and production	1275	3.0%	148	0.4%
54	Trade services	1261	3.0%	2437	5.8%
53	Construction and construction works	1231	2.9%	5916	14.1%
65	Administrative services of the government and for the communit	856	2.0%	1752	4.2%
60	Telecommunications, transmission and information services	762	1.8%	1280	3.0%
40	Other chemical products	691	1.6%	492	1.2%
10	Fish and other aquatic products (except shrimp)	610	1.5%	244	0.6%
9	Live or fresh shrimp and shrimp larvae	563	1.3%	38	0.1%
57	Restaurant services	517	1.2%	881	2.1%
7	Live animals and animal products	504	1.2%	525	1.2%
36	Products of treated wood, cork and other materials	443	1.1%	26	0.1%
70	Association services; leisure; cultural and sports	416	1.0%	725	1.7%
43	Glass, ceramics and refractories	397	0.9%	81	0.2%
5	Oilseeds and industrialised products	395	0.9%	51	0.1%
16	Meat, meat products and by-products	242	0.6%	861	2.0%
63	Real estate services	232	0.6%	946	2.3%
47	Machinery, equipment and electrical appliances	193	0.5%	290	0.7%
46	Processed metal products	190	0.5%	284	0.7%
56	Accommodation services	188	0.4%	157	0.4%
17	Elaborated shrimp	187	0.4%	1081	2.6%
69	Non-market social and health services	183	0.4%	584	1.4%
1	Banana, coffee and cocoa	175	0.4%	519	1.2%
42	Plastic products	164	0.4%	44	0.1%
37	Pulp, paper and cardboard, editorial products and others	158	0.4%	145	0.3%
6	Services related to agriculture	142	0.3%	0	0.0%
19	Prepared and preserved fish and other aquatic species	142	0.3%	520	1.2%
13	Services related to oil and natural gas	136	0.3%	0	0.0%
50	Other manufactured products	130	0.3%	44	0.1%
33	Threads, spinning, weaving and confection	129	0.3%	136	0.3%
25	Sugar, brown sugar and molasses	129	0.3%	192	0.5%
61	Financial intermediation services	127	0.3%	211	0.5%
4	Tubers, Vegetables, melons and fruits	118	0.3%	211	0.5%
15	No-metallic minerals	117	0.3%	-1	0.0%
45	Common metals	117	0.3%	194	0.5%
29	Various food products	107	0.3%	359	0.9%
14	Metallic minerals	106	0.3%	30	0.1%
67	Public education services	101	0.2%	259	0.6%
18	Fish and other processed aquatic products	87	0.2%	280	0.7%
30	Alcoholic beverages	81	0.2%	245	0.6%
48	Transportation equipment	77	0.2%	146	0.3%
3	Flowers and buds	76	0.2%	296	0.7%
21	Processed dairy products	67	0.2%	411	1.0%
2	Cereals	60	0.1%	17	0.0%
52	Water, sanitation and gas services (oil exc)	56	0.1%	41	0.1%
20	Crude and refined oils	55	0.1%	211	0.5%
23	Bakery products	50	0.1%	186	0.4%
49	Furniture	49	0.1%	348	0.8%

cont…

Cod.	Activity	Direct emission	%	Total emission	%
8	Forestry products	46	0.1%	47	0.1%
31	Non-alcoholic beverages	45	0.1%	202	0.5%
28	Processed coffee products	42	0.1%	84	0.2%
59	Postal and courier services	39	0.1%	60	0.1%
24	Noodles, macaroni and other similar farinaceous products	39	0.1%	54	0.1%
11	Aquaculture products (except shrimp)	39	0.1%	44	0.1%
34	Clothing	35	0.1%	146	0.3%
26	Elaborated cocoa, chocolate and confectionery products	31	0.1%	100	0.2%
39	Basic chemical products, fertilizers and primary plastics	30	0.1%	6	0.0%
22	Grain mill products	29	0.1%	201	0.5%
35	Leather, leather products and footwear	25	0.1%	86	0.2%
68	Social and health services	22	0.1%	111	0.3%
66	Private education services	20	0.0%	122	0.3%
55	Repair and maintenance services of motor vehicles and motorc	19	0.0%	21	0.1%
41	Rubber products	14	0.0%	23	0.1%
27	Animal food	12	0.0%	37	0.1%
62	Insurance services and pension funds	11	0.0%	48	0.1%
32	Elaborate tobacco	0	0.0%	15	0.0%
71	Domestic service	0	0.0%	0	0.0%
	Total	**42,019**	**100%**	**42,019**	**100%**

Source: prepared by the authors based on the estimation of CO_2 emissions (Table A.1) and IO Matrix 2013 (BCE, 2016).

Table A.3. Classification of economic activities in key sectors, and sectors relevant from the supply or demand perspective.

Cod.	Activity	μj/μ	cvj	μi/μ	cvi	Classification
1	Banana, coffee and cocoa	0.9	5.5	0.3	4.8	rest
2	Cereals	0.0	4.6	0.2	7.5	rest
3	Flowers and buds	0.5	8.4	0.1	6.0	rest
4	Tubers, Vegetables, melons and fruits	0.4	7.8	0.2	7.2	rest
5	Oilseeds and industrialised products	0.1	3.2	1.1	7.1	relevant from supply
6	Services related to agriculture	0.0	6.4	0.3	7.9	rest
7	Live animals and animal products	0.9	4.8	0.3	3.9	rest
8	Forestry products	0.1	5.6	0.4	8.0	rest
9	Live or fresh shrimp and shrimp larvae	0.1	6.3	0.7	6.6	rest
10	Fish and other aquatic products (except shrimp)	0.4	5.9	0.8	7.2	rest
11	Aquaculture products (except shrimp)	0.1	7.3	0.1	8.1	rest
12	Crude oil and natural gas	6.6	5.0	6.2	3.4	key sector
13	Services related to oil and natural gas	0.0	6.9	1.1	6.4	relevant from supply
14	Metallic minerals	0.1	6.8	0.2	8.1	rest
15	No-metallic minerals	0.0	7.9	0.2	8.1	rest
16	Meat, meat products and by-products	1.5	6.9	0.2	4.1	relevant from demand
17	Elaborated shrimp	1.8	8.2	0.1	4.4	relevant from demand
18	Fish and other processed aquatic products	0.5	7.4	0.1	5.2	rest
19	Prepared and preserved fish and other aquatic species	0.9	8.1	0.2	5.5	rest
20	Crude and refined oils	0.4	6.9	0.1	6.7	rest
21	Processed dairy products	0.7	8.0	0.0	5.1	rest
22	Grain mill products	0.3	5.5	0.0	5.5	rest
23	Bakery products	0.3	8.1	0.1	5.7	rest
24	Noodles, macaroni and other similar farinaceous products	0.1	8.3	0.0	7.9	rest
25	Sugar, brown sugar and molasses	0.3	6.9	0.1	7.0	rest
26	Elaborated cocoa, chocolate and confectionery products	0.2	8.3	0.0	7.2	rest
27	Animal food	0.1	5.3	0.3	6.5	rest
28	Processed coffee products	0.1	8.4	0.0	7.7	rest
29	Various food products	0.6	7.9	0.1	6.0	rest
30	Alcoholic beverages	0.4	8.1	0.1	6.4	rest
31	Non-alcoholic beverages	0.3	8.3	0.1	6.4	rest
32	Elaborate tobacco	0.0	8.4	0.0	8.2	rest
33	Threads, spinning, weaving and confection	0.2	6.2	0.2	7.5	rest
34	Clothing	0.2	8.1	0.1	6.2	rest
35	Leather, leather products and footwear	0.1	8.2	0.0	7.5	rest
36	Products of treated wood, cork and other materials	0.0	6.0	0.4	5.9	rest
37	Pulp, paper and cardboard, editorial products and others	0.2	4.9	0.8	7.3	rest
38	Refined petroleum oils and other products	6.1	3.3	11.0	6.2	key sector
39	Basic chemical products, fertilizers and primary plastics	0.0	6.2	0.2	8.1	rest
40	Other chemical products	0.8	5.8	1.1	6.7	relevant from supply
41	Rubber products	0.0	8.1	0.0	8.2	rest
42	Plastic products	0.1	5.4	0.5	8.0	rest
43	Glass, ceramics and refractories	0.1	7.9	0.4	7.9	rest
44	Cement, articles of concrete and stone	-0.1	7.6	1.9	5.5	relevant from supply
45	Common metals	0.3	5.6	0.3	5.6	rest
46	Processed metal products	0.5	7.4	0.3	6.1	rest
47	Machinery, equipment and electrical appliances	0.5	6.0	0.3	6.0	rest
48	Transportation equipment	0.2	7.9	0.2	6.8	rest
49	Furniture	0.6	8.3	0.0	5.3	rest
50	Other manufactured products	0.1	4.5	0.6	7.0	rest
51	Electricity	7.2	5.2	5.8	5.9	key sector

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Cod.	Activity	μj/μ	cvj	μi/μ	cvi	Classification
52	Water, sanitation and gas services (oil exc)	0.1	6.7	0.3	7.9	rest
53	Construction and construction works	10.0	6.4	1.5	2.5	key sector
54	Trade services	4.1	1.4	4.8	3.5	key sector
55	Repair and maintenance services of motor vehicles and motorcycles	0.0	6.6	0.7	7.9	rest
56	Accommodation services	0.3	7.8	0.3	7.0	rest
57	Restaurant services	1.5	7.6	0.7	3.8	relevant from demand
58	Transport and storage services	8.4	2.3	12.6	4.3	key sector
59	Postal and courier services	0.1	7.8	0.1	8.1	rest
60	Telecommunications, transmission and information services	2.2	5.7	1.1	5.1	key sector
61	Financial intermediation services	0.4	3.6	1.0	5.5	relevant from supply
62	Insurance services and pension funds	0.1	6.7	0.3	7.5	rest
63	Real estate services	1.6	5.0	0.8	5.5	relevant from demand
64	Services provided to companies and production	0.2	1.4	6.8	5.3	relevant from supply
65	Administrative services of the government and for the community in general	3.0	8.4	1.1	3.8	key sector
66	Private education services	0.2	8.3	0.0	7.0	rest
67	Public education services	0.4	8.4	0.2	7.1	rest
68	Social and health services	0.2	8.4	0.0	7.2	rest
69	Non-market social and health services	1.0	8.4	0.2	5.6	rest
70	Association services; leisure; cultural and sports	1.2	7.4	0.6	5.7	relevant from demand
71	Domestic service	0.0	8.4	0.0	8.4	rest

Source: prepared by the authors based on the estimate of CO_2 emissions (Table A.2) and IO Matrix 2013 (BCE, 2016).

Table A.4. Comparison of type of classification of sectors according to the Ghosh and Leontief matrixes to calculate the forward linkage.

		Forward Linkages						
		Leontief			Ghosh			
Cod.	Activity	μi	μi/μ	>1	μi	μi/μ	>1	Result
1	Banana, coffee and cocoa	1.6	0.3	0.0	1.4	0.3	0.0	not change
2	Cereals	0.6	0.1	0.0	1.1	0.2	0.0	not change
3	Flowers and buds	0.7	0.1	0.0	0.5	0.1	0.0	not change
4	Tubers, Vegetables, melons and fruits	1.1	0.2	0.0	1.0	0.2	0.0	not change
5	**Oilseeds and industrialised products**	**3.7**	**0.7**	**0.0**	**5.9**	**1.1**	**1.0**	**FL Ghosh**
6	Services related to agriculture	1.3	0.2	0.0	1.4	0.3	0.0	not change
7	Live animals and animal products	4.7	0.9	0.0	1.9	0.3	0.0	not change
8	Forestry products	0.4	0.1	0.0	2.1	0.4	0.0	not change
9	Live or fresh shrimp and shrimp larvae	5.3	1.0	0.0	3.9	0.7	0.0	not change
10	**Fish and other aquatic products (except shrimp)**	**5.7**	**1.0**	**1.0**	**4.6**	**0.8**	**0.0**	**FL Leontief**
11	Aquaculture products (except shrimp)	0.4	0.1	0.0	0.4	0.1	0.0	not change
12	Crude oil and natural gas	20.7	3.7	1.0	34.3	6.2	1.0	not change
13	**Services related to oil and natural gas**	**1.3**	**0.2**	**0.0**	**6.1**	**1.1**	**1.0**	**FL Ghosh**
14	Metallic minerals	1.0	0.2	0.0	1.1	0.2	0.0	not change
15	No-metallic minerals	1.1	0.2	0.0	1.3	0.2	0.0	not change
16	Meat, meat products and by-products	2.3	0.4	0.0	0.9	0.2	0.0	not change
17	Elaborated shrimp	1.8	0.3	0.0	0.4	0.1	0.0	not change
18	Fish and other processed aquatic products	0.8	0.1	0.0	0.4	0.1	0.0	not change
19	Prepared and preserved fish and other aquatic species	1.3	0.2	0.0	1.0	0.2	0.0	not change
20	Crude and refined oils	0.5	0.1	0.0	0.4	0.1	0.0	not change
21	Processed dairy products	0.6	0.1	0.0	0.3	0.0	0.0	not change
22	Grain mill products	0.3	0.0	0.0	0.2	0.0	0.0	not change
23	Bakery products	0.5	0.1	0.0	0.3	0.1	0.0	not change
24	Noodles, macaroni and other similar farinaceous products	0.4	0.1	0.0	0.1	0.0	0.0	not change
25	Sugar, brown sugar and molasses	1.2	0.2	0.0	0.4	0.1	0.0	not change
26	Elaborated cocoa, chocolate and confectionery products	0.3	0.1	0.0	0.1	0.0	0.0	not change
27	Animal food	0.1	0.0	0.0	1.5	0.3	0.0	not change
28	Processed coffee products	0.4	0.1	0.0	0.2	0.0	0.0	not change
29	Various food products	1.0	0.2	0.0	0.3	0.1	0.0	not change
30	Alcoholic beverages	0.8	0.1	0.0	0.5	0.1	0.0	not change
31	Non-alcoholic beverages	0.4	0.1	0.0	0.3	0.1	0.0	not change
32	Elaborate tobacco	0.0	0.0	0.0	0.0	0.0	0.0	not change
33	Threads, spinning, weaving and confection	1.2	0.2	0.0	1.2	0.2	0.0	not change
34	Clothing	0.3	0.1	0.0	0.3	0.1	0.0	not change
35	Leather, leather products and footwear	0.2	0.0	0.0	0.2	0.0	0.0	not change
36	Products of treated wood, cork and other materials	4.2	0.7	0.0	2.3	0.4	0.0	not change
37	Pulp, paper and cardboard, editorial products and others	1.5	0.3	0.0	4.6	0.8	0.0	not change
38	Refined petroleum oils and other products	69.5	12.5	1.0	61.4	11.0	1.0	not change
39	Basic chemical products, fertilizers and primary plastics	0.3	0.1	0.0	1.0	0.2	0.0	not change
40	Other chemical products	6.5	1.2	1.0	6.3	1.1	1.0	not change
41	Rubber products	0.1	0.0	0.0	0.3	0.0	0.0	not change
42	Plastic products	1.5	0.3	0.0	2.8	0.5	0.0	not change
43	Glass, ceramics and refractories	3.7	0.7	0.0	2.5	0.4	0.0	not change
44	Cement, articles of concrete and stone	17.6	3.2	1.0	10.4	1.9	1.0	not change
45	Common metals	1.1	0.2	0.0	1.8	0.3	0.0	not change
46	Processed metal products	1.8	0.3	0.0	1.6	0.3	0.0	not change
47	Machinery, equipment and electrical appliances	1.8	0.3	0.0	1.8	0.3	0.0	not change
48	Transportation equipment	0.7	0.1	0.0	1.0	0.2	0.0	not change
49	Furniture	0.5	0.1	0.0	0.2	0.0	0.0	not change
50	Other manufactured products	1.2	0.2	0.0	3.5	0.6	0.0	not change
51	Electricity	63.6	11.4	1.0	32.0	5.8	1.0	not change

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Cod.	Activity	Forward Linkages						Result
		Leontief			Ghosh			
		μ^i	μ^i/μ	>1	μ^i	μ^i/μ	>1	
52	Water, sanitation and gas services (oil exc)	0.5	0.1	0.0	1.9	0.3	0.0	not change
53	Construction and construction w orks	11.6	2.1	1.0	8.6	1.5	1.0	not change
54	Trade services	11.8	2.1	1.0	26.9	4.8	1.0	not change
55	Repair and maintenance services of motor vehicles and motorcycles	0.2	0.0	0.0	3.9	0.7	0.0	not change
56	Accommodation services	1.8	0.3	0.0	1.6	0.3	0.0	not change
57	Restaurant services	4.9	0.9	0.0	3.8	0.7	0.0	not change
58	Transport and storage services	86.3	15.5	1.0	70.3	12.6	1.0	not change
59	Postal and courier services	0.4	0.1	0.0	0.4	0.1	0.0	not change
60	Telecommunications, transmission and information services	7.2	1.3	1.0	6.1	1.1	1.0	not change
61	**Financial intermediation services**	**1.2**	**0.2**	**0.0**	**5.6**	**1.0**	**1.0**	**FL Ghosh**
62	Insurance services and pension funds	0.1	0.0	0.0	1.5	0.3	0.0	not change
63	Real estate services	2.2	0.4	0.0	4.6	0.8	0.0	not change
64	Services provided to companies and production	12.0	2.2	1.0	37.6	6.8	1.0	not change
65	Administrative services of the government and for the community in general	8.0	1.4	1.0	6.4	1.1	1.0	not change
66	Private education services	0.2	0.0	0.0	0.2	0.0	0.0	not change
67	Public education services	0.9	0.2	0.0	0.9	0.2	0.0	not change
68	Social and health services	0.2	0.0	0.0	0.2	0.0	0.0	not change
69	Non-market social and health services	1.7	0.3	0.0	1.3	0.2	0.0	not change
70	Association services; leisure; cultural and sports	3.9	0.7	0.0	3.6	0.6	0.0	not change
71	Domestic service	0.0	0.0	0.0	0.0	0.0	0.0	not change
	Promedio	**5.6**			**5.6**			

Source: computed by the authors with the CO_2 emission estimation (Table A.2) and the IO Matrix 2013 (BCE, 2016).

Table A.5. Pure and own components of backward and forward linkages.

Cod.	Activity	Backward linkage			Forward linkage		
		μi	own	pure	μi	own	pure
1	Banana, coffee and cocoa	4.9	1.5	3.4	1.4	1.2	0.2
2	Cereals	0.2	0.0	0.1	1.1	0.5	0.6
3	Flowers and buds	2.8	0.7	2.1	0.5	0.5	0.0
4	Tubers, Vegetables, melons and fruits	2.0	1.0	1.0	1.0	0.9	0.1
5	Oilseeds and industrialised products	0.5	0.3	0.2	5.9	3.2	2.8
6	Services related to agriculture	0.0	0.0	0.0	1.4	1.0	0.4
7	Live animals and animal products	4.9	1.9	3.0	1.9	1.4	0.5
8	Forestry products	0.4	0.1	0.3	2.1	0.4	1.7
9	Live or fresh shrimp and shrimp larvae	0.4	0.3	0.1	3.9	3.3	0.6
10	Fish and other aquatic products (except shrimp)	2.3	2.0	0.3	4.6	4.2	0.4
11	Aquaculture products (except shrimp)	0.4	0.2	0.2	0.4	0.3	0.1
12	Crude oil and natural gas	36.9	19.2	17.7	34.3	14.9	19.4
13	Services related to oil and natural gas	0.0	0.0	0.0	6.1	1.0	5.0
14	Metallic minerals	0.3	0.2	0.1	1.1	0.7	0.3
15	No-metallic minerals	0.0	0.0	0.0	1.3	0.7	0.6
16	Meat, meat products and by-products	8.1	1.9	6.2	0.9	0.7	0.2
17	Elaborated shrimp	10.2	1.7	8.4	0.4	0.4	0.0
18	Fish and other processed aquatic products	2.6	0.6	2.0	0.4	0.3	0.1
19	Prepared and preserved fish and other aquatic species	4.9	1.3	3.6	1.0	0.8	0.1
20	Crude and refined oils	2.0	0.4	1.6	0.4	0.3	0.2
21	Processed dairy products	3.9	0.6	3.3	0.3	0.2	0.1
22	Grain mill products	1.9	0.2	1.7	0.2	0.1	0.1
23	Bakery products	1.8	0.4	1.3	0.3	0.2	0.1
24	Noodles, macaroni and other similar farinaceous products	0.5	0.3	0.2	0.1	0.1	0.0
25	Sugar, brown sugar and molasses	1.8	0.8	1.0	0.4	0.3	0.0
26	Elaborated cocoa, chocolate and confectionery products	0.9	0.3	0.7	0.1	0.1	0.0
27	Animal food	0.3	0.0	0.3	1.5	0.1	1.5
28	Processed coffee products	0.8	0.4	0.4	0.2	0.2	0.0
29	Various food products	3.4	1.0	2.4	0.3	0.3	0.0
30	Alcoholic beverages	2.3	0.7	1.6	0.5	0.4	0.1
31	Non-alcoholic beverages	1.9	0.4	1.5	0.3	0.2	0.0
32	Elaborate tobacco	0.1	0.0	0.1	0.0	0.0	0.0
33	Threads, spinning, weaving and confection	1.3	0.6	0.6	1.2	0.8	0.3
34	Clothing	1.4	0.3	1.1	0.3	0.2	0.1
35	Leather, leather products and footwear	0.8	0.2	0.6	0.2	0.1	0.1
36	Products of treated wood, cork and other materials	0.2	0.2	0.1	2.3	1.9	0.4
37	Pulp, paper and cardboard, editorial products and others	1.4	0.6	0.8	4.6	1.1	3.5
38	Refined petroleum oils and other products	34.1	32.3	1.8	61.4	44.8	16.6
39	Basic chemical products, fertilizers and primary plastics	0.1	0.0	0.0	1.0	0.2	0.7
40	Other chemical products	4.6	3.6	1.0	6.3	5.1	1.2
41	Rubber products	0.2	0.1	0.1	0.3	0.1	0.2
42	Plastic products	0.4	0.3	0.1	2.8	1.4	1.4
43	Glass, ceramics and refractories	0.8	0.5	0.2	2.5	2.3	0.2
44	Cement, articles of concrete and stone	-0.3	-0.3	-0.1	10.4	9.8	0.6
45	Common metals	1.8	0.6	1.2	1.8	0.7	1.1
46	Processed metal products	2.7	1.3	1.3	1.6	1.2	0.4
47	Machinery, equipment and electrical appliances	2.7	1.4	1.4	1.8	1.1	0.7
48	Transportation equipment	1.4	0.7	0.7	1.0	0.6	0.4
49	Furniture	3.3	0.4	2.8	0.2	0.2	0.0
50	Other manufactured products	0.4	0.2	0.2	3.5	0.9	2.6
51	Electricity	40.0	35.2	4.8	32.0	30.7	1.3
52	Water, sanitation and gas services (oil exc)	0.4	0.2	0.2	1.9	0.4	1.4
53	Construction and construction works	55.6	10.9	44.6	8.6	7.5	1.1
54	Trade services	22.9	6.5	16.4	26.9	8.8	18.0
55	Repair and maintenance services of motor vehicles and motorcycles	0.2	0.1	0.1	3.9	0.2	3.7
56	Accommodation services	1.5	0.9	0.6	1.6	1.1	0.5
57	Restaurant services	8.3	4.3	4.0	3.8	2.9	0.8
58	Transport and storage services	46.8	38.8	8.1	70.3	61.1	9.2
59	Postal and courier services	0.6	0.2	0.3	0.4	0.2	0.2
60	Telecommunications, transmission and information services	12.0	5.9	6.1	6.1	4.6	1.5

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61	Financial intermediation services	2.0	0.5	1.5	5.6	0.8	4.8
62	Insurance services and pension funds	0.5	0.1	0.4	1.5	0.1	1.4
63	Real estate services	8.9	1.8	7.1	4.6	1.6	3.0
64	Services provided to companies and production	1.4	0.9	0.5	37.6	10.6	27.0
65	Administrative services of the government and for the community in general	16.5	8.0	8.4	6.4	6.4	0.0
66	Private education services	1.1	0.2	1.0	0.2	0.2	0.0
67	Public education services	2.4	0.9	1.5	0.9	0.9	0.0
68	Social and health services	1.0	0.2	0.8	0.2	0.2	0.0
69	Non-market social and health services	5.5	1.7	3.8	1.3	1.3	0.0
70	Association services; leisure; cultural and sports	6.8	3.4	3.5	3.6	2.5	1.0
71	Domestic service	0.0	0.0	0.0	0.0	0.0	0.0

Source: prepared by the authors based on the CO_2 emissions estimation (Table A.2) and the IO Matrix 2013 (BCE, 2016).

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