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Relevant sectors in CO_2 emissions in Ecuador and implications for mitigation policies

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ABSTRACT

We analyse the relationship between the economic structure and CO_2 emissions from fossil sources for Ecuador, a small developing country that exports raw materials. We use an input–output method to identify the relevant economic sectors in CO_2 emissions. Sectoral emissions are decomposed into an own component (emitted directly by its productive process) and an induced component (induced by its interrelation with other sectors). We use the input–output table for 2013 and construct a highly disaggregated vector of CO_2 emissions based on fossil energy consumption. The results show that 19 economic sectors (from a total of 71) are relevant in CO_2 emissions, of which 8 are classified as key sectors: transportation, refined petroleum, crude oil, electricity, trade services, construction, public administration services and telecommunication services. Despite the last four sectors represent only 9.8% of direct CO_2 emissions, they are indirectly responsible for 27.1% of total emissions due to their production chains. Our research orientates effective mitigation policy, as it makes possible to determine which sectors, with a high own component of emissions, require measures such as technological improvements and best practices, and which sectors, with a high induced component of emissions, require intersectoral policies, depending on their supply or demand linkages.

1. Introducción

Ecuador has developed the concept of "good living" ("*buen vivir*") as a roadmap for its growth and development (SENPLADES, 2013). The "good living" has its origin in the Andean concept called "*Sumak Kawsay*"", which served as inspiration for the drafting of the 2008 constitution of Ecuador. The *Sumak Kawsay* is a multidimensional paradigm that proposes new ways of life and has as its central axis the harmonious development between human beings and nature, from a biocentric coexistence perspective (Ramírez-Cendrero et al., 2017). However, combining these development principles with economic practice can be complex without adequate information and tools to harmonise and find an adequate balance between the economic, environmental and social dimensions.

According to the Ministry of Energy and Non-Renewable Natural Resources (MERNNR, 2018), between 2008 and 2018, Ecuador's population increased by 3.2 million people, its GDP by 33%, and per capita energy by 15.3%. This led to greater energy demand and production, which in the case of Ecuador comes mainly from fossil sources. Although in recent years the production of energy from renewable sources, particularly hydroelectric, has increased significantly (by 33% between 2008 and 2018), oil remains, by far, the most important primary energy source. In 2018, total primary energy production (including oil exports) was 216 million barrels of oil equivalent (BOE), of which 87.5% was oil and only 7.8% was from renewable sources.

CO_2 emissions are closely linked to the consumption of fossil fuels, hence the importance that different institutions attach to energy policies to mitigate them. In order to contextualise and see in historical perspective the importance of CO_2 emissions linked to the consumption of fossil energy sources on total greenhouse gas (GHG) emissions in Ecuador, we have drawn Fig. 1.

Both CO_2 emissions and total GHG emissions experienced a sustained growth since 1999. The share of CO_2 in total GHG emissions, measured in terms of CO_2 equivalent, has been increasing throughout the period reaching 61.1% in 2014, almost two thirds of total GHGs.[1] The CO_2 emissions from industrial processes, not related to energy consumption,

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[1] The emissions of nitrous oxide (N_2O) and methane (CH_4) are related to agriculture and waste treatment.

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have remained more or less constant, representing only around 6% of total CO_2 emissions.[2] Thus, without ignoring the importance of the rest of GHG, given its weight on total emissions, the particular analysis of CO_2 emitted from the combustion of fossil fuels is of great relevance in the Ecuadorian case.

The concern about the increase in energy consumption and CO_2 emissions in Ecuador and the policies implemented in recent years has attracted the attention of several authors. Robalino-López et al. (2014) analysed how changes in the energy matrix and in GDP would affect the country's CO_2 emissions and the importance of energy efficiency and reducing the share of fossil energy. Arroyo and Miguel (2019) and Castro et al. (2019) projected the energy demand of the country until 2030, its implication in terms of CO_2 emissions, and the effect of certain energy policies at the sectoral level. Cevallos (2016) analysed the transport sector with respect to its energy consumption, efficiency problems and its impact on CO_2 emissions. Martínez et al. (2017) analysed the CO_2 emissions and the economic impacts of the energy efficiency program called the National Efficient Kitchen Program (NECP) in Ecuador.

Nevertheless, a major problem for the research on the issue is that Ecuador has limited official information on CO_2 emissions at the sectoral level. The most complete official source of information on GHG emissions and environmental policy is the Third National Communication of Ecuador to the United Nations Framework Convention on Climate Change (Ministry of the Environment of Ecuador, 2017), which contains estimates of CO_2 emissions for the year 2012. However, this information only provides a breakdown into four sectors according to the information from the National Energy Balance.[3] Therefore, although policy-makers and researchers have analysed sectoral energy consumption and CO_2 emissions, these analyses have not considered a broader sector breakdown, which would make it possible to highlight other sectors that may be relevant in terms of CO_2 emissions. Nor have they taken into account the sectoral interrelationships that exist in the economy, which would make it possible to show the total weight (direct and indirect) that the different economic activities (or sectors) have in

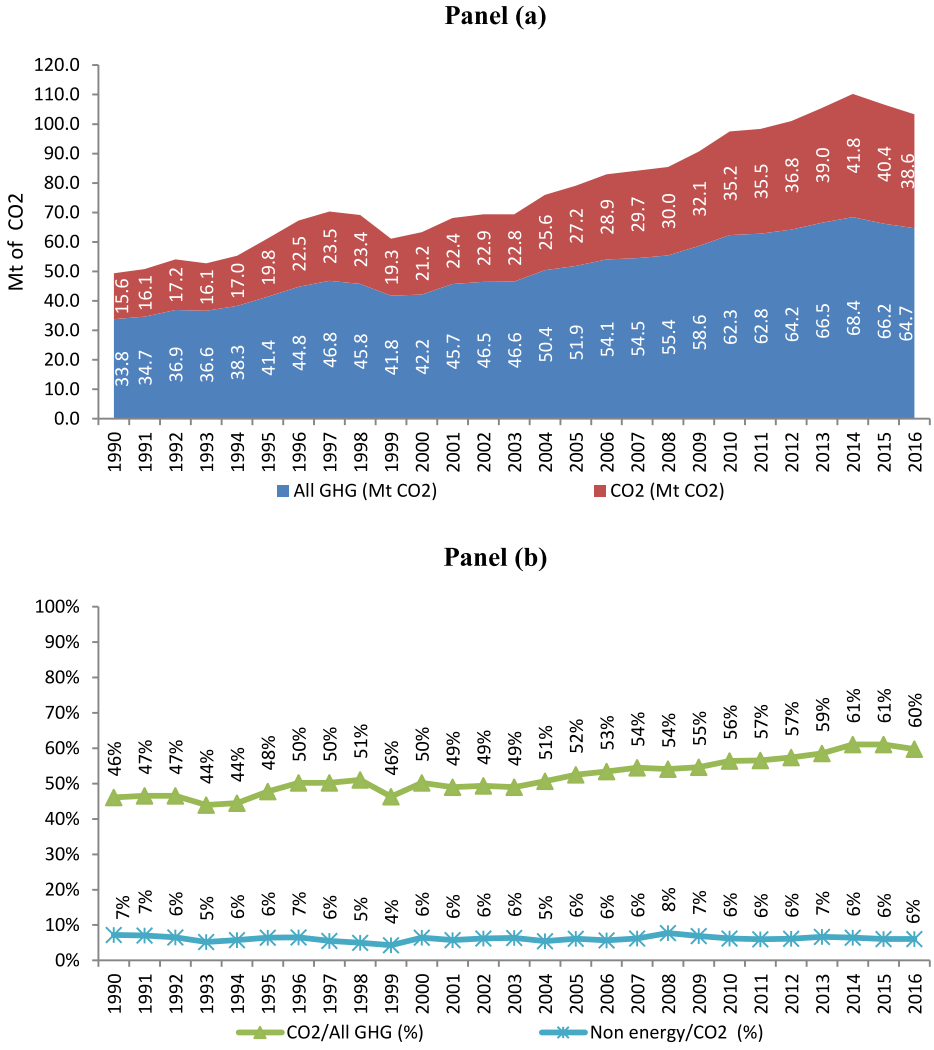

Fig. 1. CO_2 emissions and their link with total GHG emissions and non-energy emissions in Ecuador (1990–2016).
(Source: prepared by the authors based on World Resources Institute (2019))

[2] The CO_2 emissions related to industrial processes refer almost entirely to the manufacture of cement.

[3] The most up-to-date information regarding CO_2 emissions from fossil sources, published in the National Energy Balance, is of 2019; however, the breakdowns are only available for the following large groups: Energy industries, Manufacturing and construction industries, Transportation, and Other sectors (Commercial/Institutional, Residential and Agriculture/Forestry/fishing).

CO_2 emissions. That is why, for a small developing country that exports raw materials, such as Ecuador, an analysis of this type is relevant, since it would shed light on the most efficient way to establish mitigation measures proposed by both policy-makers and researchers.

The objective of our work is to analyse the links between the productive structure and CO_2 emissions in Ecuador. For this reason, we have omitted the study of the emissions directly linked to the activities of families (heating, cooling and lighting). According to IEA (2019), residential emissions in 2017 amounted to 3930.6 kt of CO_2, 11.5% of total emissions. Given the nature of consumer activities, the analysis of these emissions should be approached from another perspective. We propose the use of the environmentally extended input–output (IO) approach. 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 IO model of Leontief (1936) has been developed and used in the study of multiple issues related to economics. Regarding the determination of "key sectors", the first proposals were those of Rasmussen (1956). The information contained in an IO matrix allows the detection of the key sectors of an economy based on the set of sectoral interdependencies. In general, the methodology of key sectors can be applied to any vector of sectoral coefficients. In the environmental field, Alcántara (1995) analysed the key sectors in SOx emissions for Catalonia (Spain), Lenzen (1998) investigated GHGs and primary energy consumption through an analysis of Australian domestic production and imports, and Duarte et al. (2002) applied this method to the use of water in the Spanish Economy.

The method applied in this work follows the line of studies such as 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 income increases, and Imori and Guilhoto (2007), who used this methodology to analyse the key sectors in CO_2 emissions in Brazil. Alcántara et al. (2010) broaden the analysis of key sectors through a decomposition of the supply and demand multipliers into "own" and "pure" components (with "pure" component referring to what we call "induced" component in this paper), applied to the analysis of electricity consumption in Spain, in order to make recommendations of energy policy. In the same line, Jodar (2011) determined the key sectors of the Swiss economy and decomposed forward and backward linkages into induced and own components. Piaggio (2013) and Piaggio et al. (2014) also identified the key sectors in GHG emissions for Uruguay and applied multipliers decomposition. Regarding the Ecuadorian case, although the IO approach has been used in several investigations for the determination of key sectors (see Gachet, 2005; Artola, 2009; Fernández, 2007; Aguilar, 2014), it has not been applied to environmental issues. In this paper we will show the sectoral interdependencies between the different sectors, in order to form a basic framework for the design of CO_2 mitigation policies.

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, policy implications and conclusions are presented in Section 5.

2. Methodology for the analysis of key sectors

We start from 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. $\mathbf{x}$ can be expressed as $(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$, being $(\mathbf{I}-\mathbf{A})^{-1} = \mathbf{B}$ the Leontief inverse matrix.[4] The methodology to determine the key sectors in the emission of CO_2 described below follows the proposal by Alcántara (2007). We define $\mathbf{c}_{nx1}$ 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 $\mathbf{c}'\mathbf{x} = E$, where E is a scalar that measures total CO_2 emissions. Replacing $\mathbf{x}$ with its equivalent of the Leontief model, we have $\mathbf{e}^{\mathbf{d}}_{nx1} = \widehat{\mathbf{c}}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$, where $\mathbf{e}^{\mathbf{d}}_{nx1}$ is the vector of sectoral direct emission. We can now obtain the demand multipliers by expressing the final demand of a particular sector as a proportion of the total final demand (Hazari, 1970). From the final demand vector, a distribution vector $\widetilde{\mathbf{y}}$ is defined, such that $\sum_i \widetilde{y} = 1$. In this way, the backward linkage is redefined as:

$$\boldsymbol{\mu}'_{\mathbf{y}} 1xn = \mathbf{c}'(\mathbf{I}-\mathbf{A})^{-1}\widehat{\widetilde{\mathbf{y}}} \tag{1}$$

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.[5] Following the Ghosh model, $\mathbf{x}' = \mathbf{v}'(\mathbf{I}-\mathbf{D})^{-1}$, where $(\mathbf{I}-\mathbf{D})^{-1} = \boldsymbol{G}$ is the Ghosh inverse matrix, $\mathbf{D}$ is the matrix of distribution coefficients, $\mathbf{x}$ is the vector of production and $\mathbf{v}$ the vector of primary inputs used for production. Relating it to the emission vector, we have $\mathbf{e}^{\mathbf{d}}_{1xn} = \mathbf{v}'[\mathbf{I}-\mathbf{D}]^{-1}\widehat{\mathbf{c}}$, where $\mathbf{e}^{\mathbf{d}}_{1xn}$ is the vector of sectoral direct emission obtained from a supply perspective. As in the demand case, we define a new distribution vector of primary inputs, $\widetilde{\mathbf{v}}$, such that $\sum_i \widetilde{v} = 1$. The supply multiplier[6] is then redefined as:

$$\boldsymbol{\mu}_{\mathbf{v}_{nx1}} = \widehat{\widetilde{\mathbf{v}}}(\mathbf{I}-\mathbf{D})^{-1}\mathbf{c} \tag{2}$$

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

The mean of the multipliers is given by $\mu = \frac{\boldsymbol{\mu}'_{\mathbf{y}}\mathbf{u}}{\mathbf{n}} = \frac{\boldsymbol{\mu}'_{\mathbf{v}}\mathbf{u}}{\mathbf{n}}$, where n is the number of sectors considered and $\mathbf{u}$ a unit vector. The comparison of the multipliers obtained in (1) and (2) with the mean allows us a first sectoral classification, defined in the upper part of Table 1, which is the conventional typology in the analysis of key sectors. To calibrate whether the *j-th* activity affects all activities uniformly or not, we use the coefficient of variation following the proposal of Rasmusen (1956).

Thus, for the demand case, the coefficient would be:

$$CV^{y}_{j} = \frac{\sqrt{\frac{1}{\mathbf{n}-1}\sum_{\mathbf{i}=1}^{\mathbf{n}}\left(\mathbf{a}_{\mathbf{ij}} - \frac{1}{\mathbf{n}}\sum_{\mathbf{i}=1}^{\mathbf{n}}\mathbf{a}_{\mathbf{ij}}\right)^2}}{\frac{1}{\mathbf{n}}\sum_{\mathbf{i}=1}^{\mathbf{n}}\mathbf{a}_{\mathbf{ij}}} \tag{3}$$

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

[4] 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.

[5] Several authors argue that the Leontief inverse matrix is not adequate to measure (direct or total) forward linkages (Dietzenbacher and Van der Linden, 1997; Miller and Blair, 2009). 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 $\mathbf{A}$ be constant.

[6] 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.

Table 1
Classification of sectors.

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

Source: Adapted from Jodar (2011).

$$CV_i^v = \frac{\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(d_{ij} - \frac{1}{n}\sum_{j=1}^{n} d_{ij}\right)^2}}{\frac{1}{n}\sum_{j=1}^{n} d_{ij}} \quad (4)$$

Moreover, distinguishing between the pollution generated by an activity due to its own production process and the pollution induced in other activities is very useful for the design of mitigation policies. Alcántara et al. (2010) propose decomposing the backward and forward linkages into two induced and own components. We use expressions (1) and (2) for decomposing the supply and demand weighted multipliers, separating the external and internal sectoral links, respectively.

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

$$\mu_{y_j}^{own} = c_j B_{jj} \tilde{y}_j \quad (5)$$

$$\mu_{y_j}^{induced} = \sum_{i \neq j} c_i B_{ij} \tilde{y}_j \quad (6)$$

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

$$\mu_{v_i}^{own} = c_i G_{ii} \tilde{v}_i \quad (7)$$

$$\mu_{v_i}^{induced} = \sum_{j \neq i} c_j G_{ij} \tilde{v}_i \quad (8)$$

In 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 (Alcántara et al., 2010; Piaggio et al., 2014). In activities with a high induced 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. Furthermore, when more than one activity is involved in the process, specific policies are not enough, but intersectoral policies must be used. Finally, activities with a high induced backward component 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.

Table 1 shows the classification of sectors according to their relevance.

3. Data description

For the development of this research, the IO tables published by the Central Bank of Ecuador (BCE) were used for 2013. 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, given the lack of data disaggregated at that level, we made our own estimate to allow a more in-depth look at sectoral interrelationships. 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 2013 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 2013 provided by BCE (2016).

The procedure used was to relate the information published in the SUT for 2013 (disaggregated to 277 products) with the information coming from the energy balance published by the Coordinating Ministry of Strategic Sectors of Ecuador (MICSE). The goal was to build a total utilization vector of KBOEs for each energy source, for the productive sector (excluding residential use and exports). This energy use vector shows the total primary and secondary energy used by the productive sector, including the oil refining process. However, some energy sources in the use table had to be added so that they were comparable with the energy balance categories.[7]

The data to build the emission matrix are the result of linearly distributing the transformations described in the previous paragraph to the total KBOEs per energy source among the different industries. This distribution is based on their participation in the total intermediate consumption of each energy source, assuming that prices are the same between different industries, which, given the existing policies on fuels, turns out to be a valid assumption. The results of the estimation, together with other relevant variables of each activity, are presented in Table 2.

This estimate allows us to have the direct CO_2 emissions for 2013, disaggregated for the 71 activities of the IO matrix, which opens the door to carry out more in-depth analyses of the emissions from fossil sources.

4. Main results and discussion

The total (direct and indirect) emissions from the different sectors were calculated for the 71 economic activities of the IO matrix in 2013 (Table A.1 in the Annex). A large part of the direct emissions of the different productive sectors ultimately serve to facilitate the production of other sectors (Alcántara and Padilla, 2009). A clear example is the activity (58) "Transport and storage services", which represents 21.9% of direct emissions of the productive system, while it only represents 11.9% of total (direct and indirect) emissions from a final demand

[7] The national accounts heading "Other fuels and petroleum oils (including lubricants)" includes "airplane gasoline (Jet Fuel/Turbo)" and "other non-energy petroleum products". For this reason, all consumption outside the transport industry is eliminated and it is assumed that the total energy consumption of "Other fuels and petroleum oils (including lubricants)" is concentrated in the transport industry. Subsequently, the "Gasolines" and "Naphtha and natural gasoline" were added to the previous items in the use table in such a way that it is comparable to the "Petroleum products" heading of the energy balance. The uses of "Other fuels and petroleum oils (including lubricants)" outside the transport industry are eliminated and it is assumed that the use in the transport industry corresponds to "Kerosene and Turbo". Finally, the items "Electric power" and "Transmission and distribution services" are added.

Table 2
Estimation of CO_2 emissions by economic activity for Ecuador for 2013, total output, value added and final demand.

Cod.	Activity	Direct Emission (Kt CO_2)	%	Total output (million US$)	Direct emission intensity (TCO_2/million US$)	Value Added (million US$)	Final Demand (million US$)
58	Transport and storage services	9189	21.87%	8505	1080.4	4337	3495
38	Refined petroleum oils and other products	7399	17.61%	3830	1931.9	439	1759
51	Electricity	6773	16.12%	2769	2445.5	671	1006
12	Crude oil and natural gas	2200	5.24%	14,424	152.5	10,014	13,356
44	Cement, articles of concrete and stone	1870	4.45%	1409	1326.8	613	−19
64	Services provided to companies and production	1275	3.03%	8648	147.4	6639	564
54	Trade services	1261	3.00%	14,903	84.6	9763	8004
53	Construction and construction works	1231	2.93%	17,829	69.0	10,151	16,843
65	Administrative services of the government and for the community in general	856	2.04%	7790	109.9	5849	7790
60	Telecommunications, transmission and information services	762	1.81%	3750	203.2	1925	2937
40	Other chemical products	691	1.64%	1937	356.9	941	1049
10	Fish and other aquatic products (except shrimp)	610	1.45%	685	890.2	460	237
9	Live or fresh shrimp and shrimp larvae	563	1.34%	1130	498.3	515	52
57	Restaurant services	517	1.23%	2754	187.8	1518	2432
7	Live animals and animal products	504	1.20%	2415	208.8	505	964
36	Products of treated wood, cork and other materials	443	1.06%	1514	292.9	543	53
70	Association services, leisure, cultural and sports	416	0.99%	2484	167.6	1351	2069
43	Glass, ceramics and refractories	397	0.94%	401	989.8	216	58
5	Oilseeds and industrialised products	395	0.94%	1700	232.5	1247	142
16	Meat, meat products and by-products	242	0.57%	2329	103.7	638	1862
63	Real estate services	232	0.55%	6189	37.5	4300	4994
47	Machinery, equipment and electrical appliances	193	0.46%	1267	152.2	476	863
46	Processed metal products	190	0.45%	1373	138.1	249	1020
56	Accommodation services	188	0.45%	542	347.1	291	274
17	Elaborated shrimp	187	0.44%	1995	93.7	458	1937
69	Non-market social and health services	183	0.44%	3093	59.1	1979	3093
1	Banana, coffee and cocoa	175	0.42%	2833	61.7	1839	2475
42	Plastic products	164	0.39%	871	188.3	178	159
37	Pulp, paper and cardboard, editorial products and others	158	0.38%	1551	101.7	562	499
6	Services related to agriculture	142	0.34%	351	406.0	266	0
19	Prepared and preserved fish and other aquatic species	142	0.34%	1468	97.0	816	1398
13	Services related to oil and natural gas	136	0.32%	1875	72.3	1397	0
50	Other manufactured products	130	0.31%	880	147.2	482	141
33	Threads, spinning, weaving and confection	129	0.31%	835	154.7	344	383
25	Sugar, brown sugar and molasses	129	0.31%	445	288.5	114	300
61	Financial intermediation services	127	0.30%	3455	36.9	1989	1204
4	Tubers, Vegetables, melons and fruits	118	0.28%	932	126.8	721	836
15	No metallic minerals	117	0.28%	208	564.9	117	−1
45	Common metals	117	0.28%	1380	85.1	406	667
29	Various food products	107	0.25%	780	137.0	153	741
14	Metallic minerals	106	0.25%	261	407.2	188	49
67	Public education services	101	0.24%	3717	27.1	3442	3717
18	Fish and other processed aquatic products	87	0.21%	685	127.2	201	465
30	Alcoholic beverages	81	0.19%	978	83.0	483	898
48	Transportation equipment	77	0.18%	1094	69.9	211	925
3	Flowers and buds	76	0.18%	1213	62.4	803	1205
21	Processed dairy products	67	0.16%	1233	54.2	323	1113
2	Cereals	60	0.14%	932	64.2	752	70
52	Water, sanitation and gas services (oil exc)	56	0.13%	557	100.6	413	180
20	Crude and refined oils	55	0.13%	1230	44.7	403	854
23	Bakery products	50	0.12%	894	55.9	375	832
49	Furniture	49	0.12%	1156	42.4	349	1088
8	Forestry products	46	0.11%	1245	36.9	1062	376
31	Non-alcoholic beverage	45	0.11%	710	62.9	279	669
28	Processed coffee products	42	0.10%	270	156.7	110	251
59	Postal and courier services	39	0.09%	319	122.9	156	210
24	Noodles, macaroni and other similar farinaceous products	39	0.09%	100	389.4	26	84
11	Aquaculture products (except shrimp)	39	0.09%	217	178.6	129	125
34	Clothing	35	0.08%	903	39.1	409	763
26	Elaborated cocoa, chocolate and confectionery products	31	0.07%	546	57.4	4	316
39	Basic chemical products, fertilizers and primary plastics	30	0.07%	418	71.6	158	32

(*continued on next page*)

Table 2 (*continued*)

Cod.	Activity	Direct Emission (Kt CO_2)	%	Total output (million US$)	Direct emission intensity (TCO_2/million US$)	Value Added (million US$)	Final Demand (million US$)
22	Grain mill products	29	0.07%	1308	22.5	245	974
35	Leather, leather products and footwear	25	0.06%	518	47.7	222	398
68	Social and health services	22	0.05%	1408	15.9	896	1407
66	Private education services	20	0.05%	1798	10.9	1178	1778
55	Repair and maintenance services of motor vehicles and motorcycles	19	0.04%	1148	16.4	1001	460
41	Rubber products	14	0.03%	202	66.8	98	149
27	Animal food	12	0.03%	896	13.1	168	288
62	Insurance services and pension funds	11	0.03%	1183	8.9	549	662
32	Elaborate tobacco	0	0.00%	93	4.9	43	93
71	Domestic service	-	0.00%	382	0.0	382	382
	TOTAL	**42,019**	**100.0%**	**161,145**		**90,534**	**106,446**

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

perspective. In contrast, the activity (54) "Trade services" represents 3% of direct emissions, but its weight rises to 5.8% of total (direct and indirect) emissions from a final demand perspective. This is because other activities have to increase their production to meet the demand for inputs required by this activity.

4.1. 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 (1) and (2), respectively. Additionally, their coefficients of variation were calculated, based on expressions (3) and (4). Table 3 presents the classification of the activities that were relevant according to the methodology used (following the classification criteria described in first three rows of Table 1).

Table 3 contains 19 of the 71 activities of the IO matrix of Ecuador. These 19 activities are the most relevant in terms of CO_2 emissions and are divided into: 8 key sectors (relevant from demand and supply), 5 sectors that are relevant only from demand and 6 sectors that are relevant only from supply. The eight key sectors are responsible for 70.6% of direct emissions and 67.1% of total emissions (see Table A1 in the Annex). They are key sectors because they have the highest demand (weighted backward linkages) and supply (weighted forward linkages) 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. Regarding their coefficients of variation, they are below the average in most cases. This means that the impacts are distributed evenly to the rest of the activities. However, there are differences within this group of key sectors.

Some examples will help the reader understand the classification. The activity (38) "Refined petroleum oils and other products" is key because both weighted multipliers of supply and demand are high. On the demand side, the coefficient of variation, being higher than the average, is telling us that this impact (that is 6.14 times the average) expands heterogeneously to the rest of the activities. The coefficient of variation of the supply indicates that this impact will spread more homogeneously to the rest of the activities. The activity (60) "Telecommunications" is key because its weighted demand and supply multipliers are greater than unity and, therefore, its total impacts are greater than the average. In the case of the weighted supply multipliers, the coefficient of variation is indicating that the impact spreads homogeneously to the rest of the activities; while on the demand side, the impact expands in a more heterogeneous way.

Five sectors have higher than average multipliers but only on the demand side (backward linkages). These activities have weighted multipliers close to 1 and coefficients of variation higher than the average, in most cases. This means that, faced with an increase in demand, the impact is small and expands heterogeneously to the rest of the activities (with the exception of activities 57 "Restaurant services" and 70 "Association services, leisure, culture and sports", which have low coefficients of variation and, therefore, the impact is more homogeneous).

Finally, six activities have higher than average multipliers, but only on the supply side (forward linkages). These activities have weighted multipliers close to unity (with the exception of activity (64) "Services provided to companies and production") and coefficients of variation lower than the average (with the exception of activities 44 "Cement" and 13 "Services related to oil and natural gas"). This means that, in the face of an increase in productive inputs, the impact will be small but homogeneous to the rest of the activities, while an activity such as 44 generates a high and also very heterogeneous impact; that is, affecting differently to other activities.[8]

4.2. Own and induced components of the relevant activities in the emission of CO_2

To obtain a more exact measure of the backward and forward dependence of each sector with the rest of the economy, this section presents the decomposition of the backward and forward linkages into their induced and own components for the 19 relevant sectors, based on equations (5)–(8) (Table 4). This decomposition is useful because mitigation policies require to understand sectoral linkages since they would not work in the same way in activities that have a high own component, but a low induced component, or vice versa.

[8] 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.3 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. The relevant activities from the supply-side that do change are: (13) "Services related to oil and natural gas", (5) "Oilseeds and industrialised 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.

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

Cod.	Activity	Weighted Backward Linkages		Weighted Forward Linkages		Classification
		$\mu_{y.j}/\mu$	CV_j^y	$\mu_{y.i}/\mu$	CV_j^y	
58	Transport and storage services	8.42	3.04	12.65	4.30	key sector
38	Refined petroleum oils and other products	6.14	4.65	11.04	3.41	key sector
51	Electricity	7.19	3.03	5.76	3.14	key sector
12	Crude oil and natural gas	6.63	3.42	6.18	3.80	key sector
54	Trade services	4.12	3.42	4.83	5.19	key sector
53	Construction and construction works	10.00	2.51	1.55	5.10	key sector
65	Administrative services of the government and for the community in general	2.96	2.11	1.15	-	key sector
60	Telecommunications, transmission and information services	2.16	3.75	1.09	3.59	key sector
17	Elaborated shrimp	1.83	3.94			relevant from demand
63	Real estate services	1.60	3.41			relevant from demand
57	Restaurant services	1.49	1.81			relevant from demand
16	Meat, meat products and by-products	1.45	3.49			relevant from demand
70	Association services, leisure, cultural and sports	1.23	2.40			relevant from demand
64	Services provided to companies and production			6.76	3.30	relevant from supply
44	Cement, articles of concrete and stone			1.88	8.18	relevant from supply
40	Other chemical products			1.13	3.83	relevant from supply
13	Services related to oil and natural gas			1.09	8.06	relevant from supply
5	Oilseeds and industrialised products			1.07	2.93	relevant from supply
61	Financial intermediation services			1.00	4.28	relevant from supply
	Averages	**1.00**	**3.24**	**1.00**	**4.32**	

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

Table 4
Own and induced components of the relevant activities in the emission of CO_2 (normalized).

		Weighted Backward Linkages (Normalized)		Weighted Forward Linkages (Normalized)		Classification
Cod.	Activity	$\mu_{y_j}^{induced}/\mu$	$\mu_{y_j}^{own}/\mu$	$\mu_{v_i}^{induced}/\mu$	$\mu_{v_i}^{own}/\mu$	
58	Transport and storage services	2.97	13.61	4.63	17.11	key activity
51	Electricity	1.76	12.36	0.66	8.60	key activity
38	Refined petroleum oils and other products	0.66	11.35	8.35	12.54	key activity
12	Crude oil and natural gas	6.52	6.75	9.76	4.18	key activity
53	Construction and construction works	16.47	3.84	0.54	2.10	key activity
65	Administrative services of the government and for the community in general	3.10	2.82	0.00	1.78	key activity
54	Trade services	6.05	2.28	9.07	2.47	key activity
60	Telecommunications, transmission and information services	2.25	2.09	0.74	1.29	key activity
63	Real estate services	2.60	0.64			relevant from demand
57	Restaurant services	1.47	1.51			relevant from demand
70	Association services, leisure, cultural and sports	1.27	1.18			relevant from demand
16	Meat, meat products and by-products	2.28	0.67			relevant from demand
17	Elaborated shrimp	3.12	0.60			relevant from demand
64	Services provided to companies and production			13.57	2.97	relevant from supply
44	Cement, articles of concrete and stone			0.29	2.76	relevant from supply
40	Other chemical products			0.59	1.43	relevant from supply
13	Services related to oil and natural gas			2.54	0.29	relevant from supply
5	Oilseeds and industrialised products			1.39	0.88	relevant from supply
61	Financial intermediation services			2.40	0.22	relevant from supply
	Averages	**1.00**	**1.00**	**1.00**	**1.00**	

Source: prepared by the authors based on Table A.4 (in the Annex) with BCE (2016) data.

As mentioned above, the own component of the weighted backward linkages shows how changes in the final demand of activity *j* affect the CO_2 emissions of the activity itself; while, the induced component of the weighted backward linkages shows how changes in the final demand of sector *j* cause CO_2 emissions from other activities. On the other hand, the own component of the weighted forward linkages shows how the variations in the production of sector *i* affect the CO_2 emissions of the sector *i* itself, while the induced component of the weighted forward linkages shows how the changes in production of sector *i* causes CO_2 emissions from other activities.

Table 4 contains the decomposition of the backward and forward linkages into their induced and own components, for the 19 relevant activities (the data were normalized to have the unit as average). For example, the decomposition of the weighted backward linkages of the activity (58) "Transport and storage services" indicates that a variation in the demand for this activity generates an induced effect on emissions that is 2.97 times higher than the average for the economy; while in the sector itself this increase is 13.61 times higher than the average. On the side of the weighted forward linkages, it is observed that a variation in the productive inputs of the activity (58) generates an increase in the emissions of other sectors that is 4.63 higher than the average; while, in the sector itself, this increase is 17.11 times higher than the average. The sectors are classified following the criteria described in the last six rows of Table 1.

The first three activities, (58) "Transportation and storage services", (51) "Electricity" and (38) "Refined petroleum oils and other products",

are responsible for 55.6% of direct emissions of CO_2, but only 30.6% if the direct and indirect effects are measured (see Table A1 in the Annex). We can understand this observing the relevance of the own components of the backward and forward linkages in these sectors, both in absolute magnitude and in relative terms, compared to the induced components. However, Table 3 indicates that this induced effect of lower magnitude is not negligible since it is distributed homogeneously among various activities. An implication of these findings, in terms of mitigation policy, can be clearly seen in the activity (51). Since the own effect is much higher than the induced effect, the mitigation policy must be directed towards the sector itself, for example, through energy efficiency and the generation of electricity with renewable sources.

The analysis for activities (58) "Transportation and storage services" and (38) "Refined petroleum oils and other products" is similar, since their own components are more important than their induced components. However, an important nuance is that the induced component of the activity (38) is not minor, which means that an increase in this activity will cause other sectors to pollute.

A characteristic of these 3 sectors is that all of them are directly related to the existing energy subsidies in Ecuador for transport, electricity and gasoline. The induced and own effects of these sectors show that, an elimination of subsidies (causing an increase in prices and a fall in demand), would involve important reductions in emissions in these activities, but the drag effect they may have on other sectors would be much smaller.

A different case is the activity (12) "Crude oil and natural gas", which has lower demand and supply multipliers, but whose induced and own components are more symmetrical. In this case, a variation in its demand and in the primary inputs of the sector itself, but also of the other sectors, has a significant effect on its CO_2 emissions. This is particularly the case of its backward linkages, where the coefficient of variation in Table 3 indicates that its induced effect is distributed more homogeneously than the average of the activities. On the supply side, the own effect is lower than the induced effect and it is also distributed in a heterogeneous way. This is due to providing more than 92% of its production to the oil refining activity. Given these characteristics, intervention policies cannot be approached in the same way as in the previous cases, since in addition to direct measures of technological improvement within the activity, indirect measures are also necessary on the sectors that supply and demand inputs from this activity. Thus, the policies for activity (12) "Crude oil and natural gas" and activities (58) "Transportation and storage services", (51) "Electricity" and (38) "Refined petroleum oils and other products" must be articulated to have the desired effect.

On the other hand, the activity (53) "Construction and construction works" has different characteristics from the previous ones, since its relevance in emissions is produced indirectly. That is why it has the highest induced component on the demand side and a much lower (but not negligible) own component. It also has a low coefficient of variation. This means that, in the face of a variation in its demand, an increase in emissions from the other sectors is generated that exceed 15 times the average and are distributed homogeneously. On the supply side, it has a much lower magnitude and its effect is concentrated in the own component. These characteristics are explained because it has a low intensity of direct emission, only 69 t CO_2 per million dollars of total production, but it is combined with a high participation in total production (11%) and in final demand (16%) (see Table 2).

As for the activity (54) "Trade services", it has low own component and high induced component, both in its backward and forward linkages; therefore, its importance in terms of emissions is indirect. This is observed in Table 2, since activity (54) is not intensive in CO_2 emissions (84.6 t CO_2 per million dollars of total production) but it has an important participation in the economy of 8% of the final demand and 10.8% of the value added. Furthermore, it should be noted that its induced forward component is greater than its induced backward component (9.07 and 6.05, respectively, see Table 4); and, observing its variation coefficients, the component is more homogeneous on the side of its forward linkages. This suggests that an adequate mitigation policy requires influencing the final demand and production of other sectors (in particular transport, financial services and professional services) and not the demand of the activity itself.

The last two activities classified as key in CO_2 emissions are (65) "Administrative services of the government and for the community in general" and (60) "Telecommunications, transmission and information services". They have similar characteristics on the demand side, since both show slightly higher induced components than their own component. Therefore, a combination of direct policies, such as technological improvements, is required, but also on those activities that provide their inputs. With regard to the supply perspective, the effect of these activities is concentrated in the own component. Therefore, a direct improvement policy on these activities will be important; in particular in the telecommunications service since its coefficient of variation indicates that the effect will be homogeneous. In the case of the administrative services of the government, as it does not provide inputs to other activities, measures to reduce its emissions should focus exclusively in the activity itself.

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 induced backward linkage component is, in general, greater than their own component. This means that they are activities that pollute indirectly, so they also require multisectoral policies.

Finally, various activities are relevant 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". Sector (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). The induced forward linkage of sector (64) 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 highly polluting activities, such as transportation, cement, electricity, or refined petroleum, among others. Therefore, the policies focused on the sectors where its production is destined would allow a reduction of the emissions of this activity. Another activity with similar characteristics is (61) "Financial intermediation services". Finally, the activities (44) "Cement, articles of concrete and stone" and (40) "Other chemical products", are activities with a high own component, so direct policies of best practices and technological improvement should be implemented. Finally, 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.

We relate our findings with the environmental policy guidelines established in the Third National Communication of Ecuador to the United Nations Framework Convention on Climate Change, which, as indicated above, constitutes the most complete document with official information for Ecuador in terms of GHG emissions and environmental policies. Table 5 presents the classification of activities based on the importance of the induced and own components, the mitigation measures established in national policy and the need for adequate environmental policy depending on the characteristics of the activity.

Source: prepared by the authors based on Third National Communication of Ecuador on Climate Change (Ministry of the Environment of Ecuador, 2017).

5. Conclusions and policy implications

Ecuador is a country with limited information on environmental

Table 5
Weighted linkages decomposition, mitigation actions and necessary policies.

Strong effect	Cod.	Activity	Mitigation actions and projects (Third National Communication of Ecuador on Climate Change, 2017)	Necessary policy
Own backward or forward component	58	Transport and storage services	Energy efficiency in transportation: replacement old vehicles (public and commercial) Mass use of bicycle Quito Metro, Cuenca Tram	Direct sectoral measures like technological improvement and best practices to reduce resource use or emissions,
	51	Electricity	Hydroelectric development, renewable energy Energy efficiency: public sector (luminaires); private (cooking, lamps); industry (ISO standards) Optimization of Electricity Generation and Energy Efficiency in the interconnected oil system: efficient use of non-renewable natural resources	
	38	Refined petroleum oils and other products	Biofuel	
	12	Crude oil and natural gas		
	57	Restaurant services		
	65	Administrative services of the government and for the community in general	Improvement of energy efficiency in public lighting by replacing technology	
	60	Telecommunications, transmission and information services		
	44	Cement, articles of concrete and stone	Destruction of Ozone Depleting Substances (ODS) in cement kilns Productive improvement of smelting plants	
	40	Other chemical products		
Induced forward component	64	Services provided to companies and production		Inter-sectoral policies
	12	Crude oil and natural gas		
	54	Trade services		
	13	Services related to oil and natural gas		
	5	Oilseeds and industrialised products		
	61	Financial intermediation services		
Induced backward component	53	Construction and construction works		Technological improvement or better practices are effective if they reduce intermediate demand to directly polluting sectors
	12	Crude oil and natural gas		
	54	Trade services		
	65	Administrative services of the government and for the community in general		
	60	Telecommunications, transmission and information services		
	70	Association services, leisure, cultural and sports		
	16	Meat, meat products and by-products		
	63	Real estate services		
	17	Elaborated shrimp		
	57	Restaurant services		

pollution disaggregated data. This explains why policy guidelines and previous empirical research only focus on activities traditionally related to pollution. An exercise of greater sectoral disaggregation (71 sectors) makes visible the relevance in CO_2 emissions of other economic activities. This disaggregation and input–output analysis allow us to identify a set of relevant sectors in CO_2 emissions in Ecuador. The contribution of this paper is to make this relevance evident by linking environmental pollution with the economic structure of the country and achieving an integrative vision of the relationship between the environment and the economy. In addition, according to the nature of their backward and forward linkages, sectoral emissions are decomposed into an own component (emitted directly by its productive process) and an induced component (induced by its interrelation with other sectors) to help the correct design of mitigation policies.

One of the key sectors in CO_2 emissions is electricity, which requires direct mitigation policies (given its high own component). Policy-makers should focus on measures that promote clean energy production and energy efficiency. The change of the energy matrix has certainly been one of the most important policies in Ecuador. Between 2008 and 2018, the construction of several hydroelectric plants allowed the generation of clean energy to increase by approximately 33%. In 2018, hydroelectric energy represented 44%, while energy from fossil sources represented 48% of electricity generation (MERNNR, 2018). However, increasing this percentage becomes difficult since not all the installed capacity comes into operation and problems begin to arise in several of these hydroelectric plants. Given the importance of fossil sources in the generation of electricity, the construction of natural gas combined cycle plants should be promoted to generate cleaner energy. Furthermore, efficiency polices and reducing losses in energy transformation and distribution are also a priority.

Two other sectors that are important for their high induced effect are refined petroleum oils and transportation. Direct measures on these sectors are also relevant, especially those based on technological improvements. In this regard, there have been two failed projects in the country: the Pacific refinery, whose construction was halted after corruption scandals; and the Esmeraldas refinery, which, despite the investment made, continues to produce fuels with high sulphur content and low octane. However, it is striking that, despite the importance of a measure like this, the multi-criteria analysis for prioritisation of actions from The Third National Communication of Ecuador to the United Nations Framework Convention on Climate Change places improving the quality of fuels at the Esmeraldas refinery as the last priority. This is so due to data availability, project development, and project benefits and barriers; elements that policy-makers could change if they recognised the importance of this measure. As for the transport sector, studies such as those by Castro et al. (2019) and Cevallos (2016) have shown the

importance of the sector regarding energy consumption and the relevance of passenger and cargo transport, as well as the increase in the fleet of light vehicles. Therefore, some measures could be the increase in both the private and public electric vehicle fleet, which have been raised through incentives for the replacement of old cars and the elimination of tariffs for the import of electric cars, as well as larger policies such as the Quito subway and Cuenca tram projects.

The policy of subsidies for energy consumption in transportation, fuels and electricity is significant in the Ecuadorian economy, which makes it difficult to adopt policies focused on increasing prices in these key sectors. Therefore, policy-makers should look at the characteristics of the sectors for policy design, since it is important to identify whether a sector pollutes directly in its production process or indirectly and whether it is responsible for the pollution generated by other sectors.

The extraction of crude oil and natural gas is other key activity. This sector is characterised by being one of the main sources of government financing and having an important weight in the economy, around 10% of GDP (BCE, 2018). Moreover, it has losses of around 2300 KBOEs in recent years, which represents 1% of energy production (MERNNR, 2018). This activity requires direct and indirect policies (given the magnitude of its induced and own components). In the case of direct policies, it is important to reduce the burning of gas generated in the production process, which involves significant CO_2 emissions and economic waste. The various alternatives to improve this process go through careful analysis and evaluation of the plants to know the flow and composition of the gases and the possibility of reusing them. Other direct measures are the recovery of energy by means of recovery turbines or turbo expanders and efficiency improvements in steam as an energy source. These policies, together with those indicated above for the electricity, transportation and oil refining sectors constitute the mix of direct and indirect policies for this activity. However, despite their relevance, no mitigation policies were identified in the Third National Communication of Ecuador to the United Nations Framework Convention on Climate Change (see Table 5), nor in the energy efficiency studies reviewed for the preparation of this work.

The construction activity is also a key sector, but it is approached tangentially by mitigation plans because the emphasis is placed on the cement, articles of concrete and stone sector. This is an error because the construction sector has stronger impacts than the cement sector due to its multisectoral linkages. Therefore, variations in the demand of this activity generate impacts, in CO_2 emissions, which are equivalent to 10 times the average of the rest of the economy. In this case, mitigation policies based on technological improvements would not be useful, because this activity is not directly responsible for emissions. What is required is to intervene to reduce the final demand. However, this is not very viable given its importance in the economy. Then, the emphasis should be on the sectors from which construction demands inputs, so that they adopt better technologies, as well as on the substitution of materials with low emissions. The activity has important links with sectors that supply raw materials, such as forestry, and with manufacturing, such as cement or wood, but it also demands a large part of inputs from service activities such as trade, professional services or transportation.

There are various sectors, such as trade services, administrative services of the government and for the community in general, telecommunications, transmission and information services, which are key sectors in CO_2 emissions that are not identified by policy-makers and researchers because they are not direct polluters. However, they have strong links with sectors that pollute directly, such as transportation, electricity, crude oil, or refined petroleum oils, among others. This type of interrelationship requires the design of multisectoral policies that are not analysed by the current actions and projects of public policy, but that are necessary to have the desired mitigation impact.

Finally, we find a group of activities that also pollute indirectly and are not monitored by academics or policy makers. However, their mitigation potential is more conservative, as they are relevant only from a supply or demand perspective. In the case of relevant activities only from a demand perspective (such as real estate services, restaurant services, meat products or elaborated shrimp), policies should focus on the activities that are suppliers of their inputs, as the increase in demand will pull polluting sectors to increase their emissions. For example, the government can review tariff and tax policies that have privileged certain activities, such as agriculture and livestock, which have polluting technologies and provide inputs to activities that are relevant from the demand-side. 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. The activities that are relevant only from the supply-side perspective, such as services provided to companies and production or services related to oil and natural gas, are highly related to sectors such as transportation, electricity, and oil extraction. The policies focused on the sectors where their production is destined would allow a reduction of the emissions of these activities. In the case of financial intermediation services, 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.

CRediT authorship contribution statement

Edwin Buenaño: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Emilio Padilla:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing. **Vicent Alcántara:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annexes

Table A.1
Direct and total CO_2 emissions by economic activity.

Cod	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%

(*continued on next page*)

Table A.1 (*continued*)

Cod	Activity	Direct emission	%	Total emission	%
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 community in general	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%
8	Forestry products	46	0.1%	47	0.1%
31	Non-alcoholic beverage	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 motorcycles	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.2
Classification of economic activities in key activities, and relevant activities from the supply or demand perspective.

Cod.	Activity	Backward Linkages		Forward Linkages		Classification
		$\mu_{y.j}/\mu$	CV_j^y	$\mu_{y.i}/\mu$	CV_j^v	
1	Banana, coffee and cocoa	0.9	2.8	0.3	3.0	rest
2	Cereals	0.0	2.8	0.2	3.6	rest
3	Flowers and buds	0.5	3.0	0.1	3.2	rest
4	Tubers, Vegetables, melons and fruits	0.4	3.6	0.2	4.2	rest
5	Oilseeds and industrialised products	0.1	3.0	1.1	2.9	relevant from supply
6	Services related to agriculture	0.0	-	0.3	3.6	rest
7	Live animals and animal products	0.9	3.0	0.3	4.5	rest
8	Forestry products	0.1	4.2	0.4	7.8	rest
9	Live or fresh shrimp and shrimp larvae	0.1	2.9	0.7	6.9	rest
10	Fish and other aquatic products (except shrimp)	0.4	2.7	0.8	5.3	rest
11	Aquaculture products (except shrimp)	0.1	3.8	0.1	3.7	rest
12	Crude oil and natural gas	6.6	3.4	6.2	3.8	key sector
13	Services related to oil and natural gas	0.0	-	1.1	8.1	relevant from supply
14	Metallic minerals	0.1	2.3	0.2	3.9	rest
15	No metallic minerals	0.0	3.0	0.2	8.0	rest
16	Meat, meat products and by-products	1.5	3.5	0.2	5.4	relevant from demand
17	Elaborated shrimp	1.8	3.9	0.1	5.4	relevant from demand
18	Fish and other processed aquatic products	0.5	3.0	0.1	4.0	rest
19	Prepared and preserved fish and other aquatic species	0.9	3.5	0.2	4.3	rest
20	Crude and refined oils	0.4	3.5	0.1	2.4	rest
21	Processed dairy products	0.7	3.1	0.0	3.8	rest
22	Grain mill products	0.3	4.8	0.0	3.3	rest
23	Bakery products	0.3	2.8	0.1	2.9	rest
24	Noodles, macaroni and other similar farinaceous products	0.1	3.1	0.0	4.0	rest
25	Sugar, brown sugar and molasses	0.3	5.0	0.1	2.3	rest
26	Elaborated cocoa, chocolate and confectionery products	0.2	3.0	0.0	3.8	rest
27	Animal food	0.1	2.9	0.3	3.3	rest
28	Processed coffee products	0.1	4.8	0.0	3.3	rest
29	Various food products	0.6	2.1	0.1	2.1	rest
30	Alcoholic beverages	0.4	4.7	0.1	3.2	rest
31	Non-alcoholic beverage	0.3	2.8	0.1	4.6	rest
32	Elaborate tobacco	0.0	4.1	0.0	-	rest
33	Threads, spinning, weaving and confection	0.2	3.0	0.2	2.6	rest
34	Clothing	0.2	4.1	0.1	5.6	rest
35	Leather, leather products and footwear	0.1	2.6	0.0	4.4	rest
36	Products of treated wood, cork and other materials	0.0	3.9	0.4	7.7	rest
37	Pulp, paper and cardboard, editorial products and others	0.2	2.9	0.8	3.1	rest
38	Refined petroleum oils and other products	6.1	4.7	11.0	3.4	key sector
39	Basic chemical products, fertilizers and primary plastics	0.0	2.9	0.2	3.6	rest
40	Other chemical products	0.8	2.9	1.1	3.8	relevant from supply
41	Rubber products	0.0	2.8	0.0	3.6	rest
42	Plastic products	0.1	3.2	0.5	4.0	rest
43	Glass, ceramics and refractories	0.1	2.7	0.4	8.1	rest
44	Cement, articles of concrete and stone	−0.1	2.5	1.9	8.2	relevant from supply
45	Common metals	0.3	3.6	0.3	4.5	rest
46	Processed metal products	0.5	3.3	0.3	6.6	rest
47	Machinery, equipment and electrical appliances	0.5	3.1	0.3	2.9	rest
48	Transportation equipment	0.2	3.0	0.2	4.0	rest
49	Furniture	0.6	3.6	0.0	4.6	rest
50	Other manufactured products	0.1	3.3	0.6	4.0	rest
51	Electricity	7.2	3.0	5.8	3.1	key sector
52	Water, sanitation and gas services (oil exc)	0.1	3.3	0.3	4.1	rest
53	Construction and construction works	10.0	2.5	1.5	5.1	key sector
54	Trade services	4.1	3.4	4.8	5.2	key sector
55	Repair and maintenance services of motor vehicles and motorcycles	0.0	3.5	0.7	3.9	rest
56	Accommodation services	0.3	2.0	0.3	3.9	rest
57	Restaurant services	1.5	1.8	0.7	3.4	relevant from demand
58	Transport and storage services	8.4	3.0	12.6	4.3	key sector
59	Postal and courier services	0.1	5.9	0.1	4.4	rest
60	Telecommunications, transmission and information services	2.2	3.7	1.1	3.6	key sector
61	Financial intermediation services	0.4	3.9	1.0	4.3	relevant from supply
62	Insurance services and pension funds	0.1	4.5	0.3	3.1	rest
63	Real estate services	1.6	3.4	0.8	3.9	relevant from demand
64	Services provided to companies and production	0.2	2.3	6.8	3.3	relevant from supply
65	Administrative services of the government and for the community in general	3.0	2.1	1.1	-	key sector
66	Private education services	0.2	2.5	0.0	3.0	rest
67	Public education services	0.4	2.3	0.2	-	rest
68	Social and health services	0.2	2.8	0.0	7.6	rest
69	Non-market social and health services	1.0	3.0	0.2	-	rest
70	Association services, leisure, cultural and sports	1.2	2.4	0.6	3.6	relevant from demand
71	Domestic service	0.0	-	0.0	-	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.3
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	μ_j	μ_j/μ	>1	μ_i	μ_i/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 beverage	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
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 works	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

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Table A.3 (*continued*)

		Forward Linkages						
		Leontief			Ghosh			
Cod.	Activity	μ_j	μ_j/μ	>1	μ_i	μ_i/μ	>1	Result
71	Domestic service	0.0	0.0	0.0	0.0	0.0	0.0	not change
	Average	**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.4
Pure and own components of backward and forward linkages.

		Backward Linkage			Forward Linkages		
Cod.	Activity	μ_j	Own	induced	μ_i	own	induced
1	Banana, coffee and cocoa	4.9	1.5	3.4	1.4	0.5	1.2
2	Cereals	0.2	0.0	0.1	1.1	0.0	0.0
3	Flowers and buds	2.8	0.7	2.1	0.5	0.2	0.8
4	Tubers, Vegetables, melons and fruits	2.0	1.0	1.0	1.0	0.3	0.4
5	Oilseeds and industrialised products	0.5	0.3	0.2	5.9	0.1	0.1
6	Services related to agriculture	0.0	0.0	0.0	1.4	0.0	0.0
7	Live animals and animal products	4.9	1.9	3.0	1.9	0.7	1.1
8	Forestry products	0.4	0.1	0.3	2.1	0.0	0.1
9	Live or fresh shrimp and shrimp larvae	0.4	0.3	0.1	3.9	0.1	0.0
10	Fish and other aquatic products (except shrimp)	2.3	2.0	0.3	4.6	0.7	0.1
11	Aquaculture products (except shrimp)	0.4	0.2	0.2	0.4	0.1	0.1
12	Crude oil and natural gas	36.9	19.2	17.7	34.3	6.7	6.5
13	Services related to oil and natural gas	0.0	0.0	0.0	6.1	0.0	0.0
14	Metallic minerals	0.3	0.2	0.1	1.1	0.1	0.0
15	No metallic minerals	0.0	0.0	0.0	1.3	0.0	0.0
16	Meat, meat products and by-products	8.1	1.9	6.2	0.9	0.7	2.3
17	Elaborated shrimp	10.2	1.7	8.4	0.4	0.6	3.1
18	Fish and other processed aquatic products	2.6	0.6	2.0	0.4	0.2	0.8
19	Prepared and preserved fish and other aquatic species	4.9	1.3	3.6	1.0	0.4	1.3
20	Crude and refined oils	2.0	0.4	1.6	0.4	0.2	0.6
21	Processed dairy products	3.9	0.6	3.3	0.3	0.2	1.2
22	Grain mill products	1.9	0.2	1.7	0.2	0.1	0.6
23	Bakery products	1.8	0.4	1.3	0.3	0.2	0.5
24	Noodles, macaroni and other similar farinaceous products	0.5	0.3	0.2	0.1	0.1	0.1
25	Sugar, brown sugar and molasses	1.8	0.8	1.0	0.4	0.3	0.4
26	Elaborated cocoa, chocolate and confectionery products	0.9	0.3	0.7	0.1	0.1	0.2
27	Animal food	0.3	0.0	0.3	1.5	0.0	0.1
28	Processed coffee products	0.8	0.4	0.4	0.2	0.1	0.1
29	Various food products	3.4	1.0	2.4	0.3	0.3	0.9
30	Alcoholic beverages	2.3	0.7	1.6	0.5	0.3	0.6
31	Non-alcoholic beverage	1.9	0.4	1.5	0.3	0.1	0.6
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	0.2	0.2
34	Clothing	1.4	0.3	1.1	0.3	0.1	0.4
35	Leather, leather products and footwear	0.8	0.2	0.6	0.2	0.1	0.2
36	Products of treated wood, cork and other materials	0.2	0.2	0.1	2.3	0.1	0.0
37	Pulp, paper and cardboard, editorial products and others	1.4	0.6	0.8	4.6	0.2	0.3
38	Refined petroleum oils and other products	34.1	32.3	1.8	61.4	11.3	0.7
39	Basic chemical products, fertilizers and primary plastics	0.1	0.0	0.0	1.0	0.0	0.0
40	Other chemical products	4.6	3.6	1.0	6.3	1.3	0.4
41	Rubber products	0.2	0.1	0.1	0.3	0.0	0.0
42	Plastic products	0.4	0.3	0.1	2.8	0.1	0.0
43	Glass, ceramics and refractories	0.8	0.5	0.2	2.5	0.2	0.1
44	Cement, articles of concrete and stone	−0.3	−0.3	−0.1	10.4	−0.1	0.0
45	Common metals	1.8	0.6	1.2	1.8	0.2	0.5
46	Processed metal products	2.7	1.3	1.3	1.6	0.5	0.5
47	Machinery, equipment and electrical appliances	2.7	1.4	1.4	1.8	0.5	0.5
48	Transportation equipment	1.4	0.7	0.7	1.0	0.2	0.3
49	Furniture	3.3	0.4	2.8	0.2	0.2	1.0
50	Other manufactured products	0.4	0.2	0.2	3.5	0.1	0.1
51	Electricity	40.0	35.2	4.8	32.0	12.4	1.8
52	Water, sanitation and gas services (oil exc)	0.4	0.2	0.2	1.9	0.1	0.1
53	Construction and construction works	55.6	10.9	44.6	8.6	3.8	16.5
54	Trade services	22.9	6.5	16.4	26.9	2.3	6.1
55	Repair and maintenance services of motor vehicles and motorcycles	0.2	0.1	0.1	3.9	0.0	0.0
56	Accommodation services	1.5	0.9	0.6	1.6	0.3	0.2
57	Restaurant services	8.3	4.3	4.0	3.8	1.5	1.5
58	Transport and storage services	46.8	38.8	8.1	70.3	13.6	3.0
59	Postal and courier services	0.6	0.2	0.3	0.4	0.1	0.1
60	Telecommunications, transmission and information services	12.0	5.9	6.1	6.1	2.1	2.2

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Table A.4 (*continued*)

Cod.	Activity	Backward Linkage			Forward Linkages		
		μ_j	Own	induced	μ_i	own	induced
61	Financial intermediation services	2.0	0.5	1.5	5.6	0.2	0.6
62	Insurance services and pension funds	0.5	0.1	0.4	1.5	0.0	0.1
63	Real estate services	8.9	1.8	7.1	4.6	0.6	2.6
64	Services provided to companies and production	1.4	0.9	0.5	37.6	0.3	0.2
65	Administrative services of the government and for the community in general	16.5	8.0	8.4	6.4	2.8	3.1
66	Private education services	1.1	0.2	1.0	0.2	0.1	0.4
67	Public education services	2.4	0.9	1.5	0.9	0.3	0.5
68	Social and health services	1.0	0.2	0.8	0.2	0.1	0.3
69	Non-market social and health services	5.5	1.7	3.8	1.3	0.6	1.4
70	Association services, leisure, cultural and sports	6.8	3.4	3.5	3.6	1.2	1.3
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 2) and the IO Matrix 2013 (BCE, 2016).

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