

Measuring an institution's environmental performance: A standardized proposal for carbon footprint assessment

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Abstract

The global contribution of all kinds of organizations to greenhouse gas (GHG) emissions is noteworthy. Calculating, reporting, reducing, and compensating for carbon footprints are the appropriate steps to take to guide companies toward a path that is compatible with their country's objectives for the fulfillment of the Paris Agreement. In Latin American countries, carbon footprint reporting is limited and incipient. This paper aims to start closing this gap by assessing the carbon footprint of a university operating in the city of Bogotá, Colombia. Based on a city input-output table (IOT) nested in a multiregional input-output (MRIO) table framework, we estimate the three categories of the carbon footprint (scopes 1, 2, and 3) identified by the Greenhouse Gas Protocol using an improved multiregional tiered hybrid analysis of the university's energy and other input expenditures. Our results show that 94% of the entire institution's footprint is attributed to scope 3, which represents indirect emissions linked to the upstream value chain. The results allow us to identify emission hotspots and their impact on the supply chain, which can be helpful for reducing costs and encouraging organizations, users, and suppliers to make more sustainable decisions.

Keywords: Corporate carbon footprint, EEMRIO, Hybrid input-output LCA model, Universities, Colombia, Public environmental performances.

Introduction

What is the role of companies in the fight against climate change? Apart from their direct involvement as polluters, should we consider their indirect responsibility for their part in global value chains? This article starts by acknowledging that companies play an important role in reducing impacts on the environment, not only because of their direct emissions but also their indirect ones; in other words, the organizations' footprints matter (Hertwich &

Peters, 2009; Kanemoto et al., 2016; Kucukvar et al., 2015). This fact may be clear enough from a developed country's point of view, where firms usually have binding commitments to national regulations (OECD, 2017), firms are influenced by social pressure (Gray et al., 2020), or because firms are aware of the challenges that climate change poses and the role they play in addressing these challenges (WEF, 2021).

However, this is far from the case in Latin American countries. In this region, climate change has never been a top policy priority given the more pressing demands of economic, political, and social issues (Marzano Franco, 2016). As a result, companies in these countries are still not calculating, reporting, or offsetting their carbon footprints at the levels seen in developed countries. In addition to this lack of evidence, there is a shortage of empirical studies that address the carbon footprint of corporations. In this paper, we take steps to fill this gap by proposing a standardized method of carbon footprint calculation and applying it to a real case of a university in Bogota, Colombia. Our proposal offers fresh evidence and valuable tools regarding the role of organizations in the climate change fight that can be incorporated into the environmental policy agenda of both the city of Bogotá and Colombia.

The Paris Agreement sets a global framework to help countries to reduce their greenhouse gas emissions to limit the increase in global temperature in the following decades. Nations are encouraged to declare their main efforts through their nationally determined contributions (NDCs), which are defined from a territorial-based perspective. Given the magnitude of the climate emergency, mitigation measures cannot be limited to a territorial perspective, and the consumption-based or footprint point of view must be considered (Peters, 2010; Tukker et al., 2020; T. Wiedmann & Lenzen, 2018). The footprint perspective is becoming more relevant given the current trends in globalization of the international segmentation of production in global value chains (Baldwin, 2011; Gereffi & Fernandez-Stark, 2011; Johnson & Noguera, 2012), which implies that our consumption decisions have consequences around the world.

Corporations play a significant role in mitigation efforts, and they are called on to contribute solutions. The way they address those challenges has different dimensions. Corporate social responsibility (CSR), for example, has been an essential feature of Fortune 500 firms, in which a majority of firms issue sustainability reports (Lyon et al., 2018) using

multiple approaches (Büyüközkan & Karabulut, 2018) and a variety of tools (Siew, 2015). Boubakri et al. (2021) assess CSR in emerging markets and find that these practices positively impact the firm's performance. Communication on a firm's carbon emissions should be sufficiently adequate to inform stakeholders (Karim et al., 2021). Reporting may have the effect of highlighting positive actions to signal environmental commitment and enhance a company's reputation with consumers (Peters, 2010). From a sustainability viewpoint, the role of a triple-bottom-line accounting framework is advocated by Wiedmann et al. (2009) in the corporate sphere as a necessary step to complement pure financial and economic outcomes with social and environmental outcomes.

A specific dimension of corporate responsibility relates to the environmental impacts, which can be evaluated according to the generated footprints. These footprints can be measured in terms of carbon, water, biodiversity, and labor, among others (Almazán-Gómez et al., 2019; Harangozó et al., 2015; Koslowski et al., 2020; Z. Li et al., 2021; Penz & Polska, 2018; Shilling et al., 2021; Wu et al., 2021). Goldstein & Newell (2019) call for the need to pay more attention to the corporate value chain to shed light on its environmental and social impacts. In the same sense, Li et al. (2019) claim that, to comply with mitigation scenarios and stay on top of state-driven interventions, it is necessary to call firms to action by addressing scope 3 emissions (indirect emissions embodied in firm's purchases), which have the potential to yield significant contributions to climate change. In this fashion, the concept of corporate carbon footprinting has emerged as a helpful tool that forces companies and institutions to calculate, report and reduce their carbon footprint (Lee et al., 2021). In addition, it is an appropriate tool to guide companies toward a path that is compatible with the country-level objectives for the fulfillment of the Paris Agreement. These aspects linked to business sustainability are already part of the business debates and strategies of hundreds of corporations and institutions worldwide.

What are Latin American companies doing in terms of corporate sustainability? According to the Global Reporting Initiative (GRI, 2021), only 60 out of 890 reviewed firms reported the GRI Standards in Latin America in 2017. Evidence for sustainability reporting was limited to large firms (Bunclark & Barcellos-Paula, 2021). Calculating and reporting the carbon footprint for direct emissions remain optional in national regulations, let alone the

indirect or upstream value chain emissions that are only reported by multinational companies operating in these countries (WRI, 2015).

Given this incipient reporting status, public institutions in Latin America, particularly educational institutions, can serve as examples by reporting environmental information on their carbon footprint volume, origin, reduction, and compensation. There is an increasing demand for universities to report their environmental impacts and commit to a more sustainable pathway. These institutions are knowledge hotspots regarding climate change because a significant part of environmental scientific research is developed in there; thus, they are privileged to become involved in mitigation and adaptation efforts (Leal Filho et al., 2018). The influence they can play as multipliers for spreading sustainability principles (Disterheft et al., 2013) can serve as a gateway and standardize a key concept to fulfill global emission control objectives. In this work, we focus on a university in Bogotá (Colombia) case study to shed light on these issues.

Colombia is one of the most biodiverse countries globally, and it has gone through a long process of social and political conflict that has usually undermined any sustainability efforts by authorities and nongovernment organizations (Rodríguez et al., 2020). Nevertheless, Colombia is engaged in the fight against climate change through a long-standing national strategy, as stated in the United Nations' 2019 Climate Action Plan and backed by its National Determined Contributions. Within this framework, the country has recently pledged a reduction in greenhouse gases (GHGs) of 51% by 2030 based on baseline scenario projections (Government of Colombia, 2020). Compliance with this commitment requires addressing mitigation measures in different areas such as transportation, construction, land use changes, and manufacturing. Firms will play a large part in those efforts.

The carbon footprint of Bogotá, where Universidad Ean is located, is approximately 26.1 MtCO₂, whereas territorial emissions amount to 14.6 MtCO₂ (Gilles et al., 2021). The city is a net importer of emissions, which is a fact that supports the well-documented dependence of cities on other regions (Long et al., 2020). The main hotspots of the emissions generated by the capital of Colombia are in China, the USA, and the rest of Colombia. In the case of EAN University, we find similar trends; however, the details of the provided tool and

the adaptation of the real case scenario applied to the university allow us to provide insightful conclusions that could help the institution reduce its environmental impact. Our results show that more than 90% of the whole footprint of the institution is attributed to scope 3, which represents indirect emissions from activities in the value chain of the organization's suppliers. Although these scope 3 emissions are generated outside its boundaries, once they are known and allocated to sectors and inputs, the university has the power to reduce them by reconsidering its consumption and selection of suppliers. Therefore, this is an opportunity to identify emissions hotspots and their impact in the supply chain, which can be useful to reduce costs and encourage organizations and suppliers to take sustainable action.

As mentioned above, the relevance of focusing on higher education institutions stems from their very nature, thereby making them well suited as examples to other organizations in the country. More generally, they can transcend international borders, sociopolitical regimes, and economic systems (Robinson et al., 2018). This article is related to other literature on the carbon footprint of universities. Larsen et al. (2013) propose one of the first studies on the carbon footprint of a university, addressing the case of a Norwegian institution using a single region input-output table (IOT) for that country. Baboulet & Lenzen (2010) use a hybrid approach combining life cycle assessment (LCA) and (single region, national) input-output analysis to measure the carbon footprint of an Australian university, and they highlight that this approach allows for evaluating environmental performance and considering mitigation alternatives across value chains. Achten et al. (2013) use an LCA approach to address the fact that the carbon footprint of universities includes more than just flying to attend conferences, involving aspects such as infrastructure-related emissions. Nevertheless, they stress the importance of the former as a major component. Ozawa-Meida et al. (2013) measure the carbon footprint of a UK university using the LCA-IO approach. Alvarez et al. (2014) apply a compound method to calculate the carbon footprint of an academic department of a Spanish university. Ridhosari & Rahman (2020) provide the case study of a university in Indonesia for some of the GHG scopes.

In Colombia, few studies address the carbon footprint of universities. An outstanding exception is Varón-Hoyos et al. (2021) who calculate the three GHG protocol scopes. However, they do not report emissions embodied in purchases (i.e., upstream in the value

chain) as in the present paper; rather, they focus on the downstream side of emissions, e.g., student and staff commuting and travel, water consumption, and waste disposal-related emissions. All the forementioned contributions shed light on different aspects of the carbon footprint of higher education institutions from different perspectives. Robinson et al. (2018) discuss several aspects of carbon footprinting in universities and propose a unified framework to measure it, in which scope 3 plays the central role given its relevance.

Our paper continues on this path of reporting indirect emissions embedded in value chains. To do so, we use a city-level environmentally-extended multiregional input-output (EEMRIO) analysis using a city IOT nested in a multiregional input-output table (MRIO) framework (Monsalve et al., 2020). The use of city-level IOT improves the detail in emissions estimates along the production chain by reducing aggregation problems (Monsalve et al., 2020; T. Wiedmann et al., 2021; T. Wiedmann & Lenzen, 2018). We propose the estimation of the three categories of the carbon footprint (scopes 1, 2, and 3) identified by the greenhouse gas protocol using a multiregional tiered hybrid analysis of the university's use of energy and any other input expenditures (S. Alvarez et al., 2019). In addition to the novel methodological contribution of developing a hybrid EEMRIO-LCA model for a nested IOT for Bogotá in the MRIO framework provided by OECD, we propose a specific approach to subtract taxes and margins from the purchases provided by the institution's accounting. This contribution is relevant because it allows for an accurate and systematic way of transforming the accounting information recorded by an organization into an expenditure vector suitable for a tiered hybrid model. In this way, we intend to provide a standardized framework to account for organizations' carbon footprints, minimizing discretion and enabling comparisons. Specific proposals such as the one developed in this work are necessary given the myriad of different analysis methods, measures and definitions currently implemented by universities in their impact assessments (Helmets et al., 2021).

By taking steps to report the three GHG protocol scopes, EAN University stands as a pioneer in the country. Thus, it serves as a reference for other higher education institutions and all kinds of other organizations. By estimating its emissions, the university will first identify major hotspots and then undertake measures to mitigate or compensate for its burden

on the climate. It could also signal good behavior to its stakeholders and serve as a role model to other universities and institutions.

The rest of this article is structured as follows. Section 2 presents the methodology together with the data and main assumptions, Section 3 presents the results of the university's carbon footprint, and Section 4 presents the general conclusions.

Materials and Methods

The main aim of this work is to provide a detailed account of the carbon footprint of a Colombian university to identify emission hotspots and propose alternatives to reduce the institution's impact. Therefore, the footprint is divided into three scopes, each of which assesses a different category of emissions according to their origin: scope 1, scope 2, and scope 3. Reporting significant scope 3 emissions is often discretionary. Both in an international climate policy-making context and at an enterprise level, there is no consistent practice to account for scope 2 and 3 emissions, even though they usually constitute the bulk of a footprint (Hertwich & Wood, 2018). One of the main contributions of this work is to propose a helpful tool and a replicable method to systematically and reliably assess the three scopes of an organization's carbon footprint.

Tiered hybrid model

Following ISO 14064-1, the carbon footprint of an organization can be divided into three scopes. Scope 1 accounts for direct emissions occurring directly inside the company's boundaries, i.e., those emissions generated from sources controlled by the organization such as vehicles, heating, etc. Indirect emissions are categorized into scopes 2 and 3. Scope 2 considers indirect energy emissions, which refers to emissions from purchased electricity and heat generation. In contrast, scope 3 gathers other indirect emissions from all the activities in the organization's value chain. Scope 3 emissions are also subdivided into different categories. This paper highlights scope 3's category 3, which represents the rest of the indirect emissions generated in the production process of fuels and electricity used by the organization that are not accounted for in scopes 1 and 2. Note that scopes 1 and 2 quantify emissions from sources that belong to the organization, while scope 3 is generated exclusively outside the organization's boundaries. Using a multiregional model to estimate

scope 3 emissions will allow, unlike most of the scope 3 estimations in the literature, the identification of the country of origin of the emissions, including differences in each country's production and pollution structures involved the global production chain.

The operational limits considered are those activities in which the entity has some decision capacity, such as the selection of suppliers, the energetic efficiency of the buildings, or the business travel by the staff. Consequently, we follow a “cradle-to-grave” approach in which we quantify all direct and indirect emissions upstream but not downstream emissions. Considering that a university is an institution that offers educational services instead of goods, it makes sense to establish this threshold because distribution, use, and disposal barely generate emissions in this case. Therefore, we account for all the emissions generated by the university’s suppliers and the university’s operations themselves. Nevertheless, we do not account for the emissions linked to activities after the service is ready to be provided, such as students' transportation to university facilities. In this way, we guarantee comprehensive coverage of the university’s emissions while maintaining relevance.

The calculation of scopes 1 and 2 is fully specified, as several institutions provide tools and guidelines for it (Greenhouse Gas Protocol, 2004; MITECO, 2019). However, there is no specific consensus on the boundaries and calculation of scope 3, as different methods and standards for quantifying the environmental performance of organizations exist (Pelletier et al., 2014). In this work, we follow and expand on the proposal by Alvarez et al. (2019) in which the carbon footprint is calculated through a tiered hybrid model that combines both LCA and MRIO techniques. LCA methods are used to determine both scope 1 and 2 emissions, while an MRIO model is applied to quantify scope 3 figures. In this way, the model presents the main advantages of both LCA and MRIO methods, namely, specificity and completeness, respectively (Rowley et al., 2009). This approach avoids underestimation of environmental impacts (Strømman et al., 2009) and reduces the truncation error (Lenzen, 2000) as it solves the boundary selection problem in LCA (Suh et al., 2004).

The tiered hybrid analysis is based on three-tiered matrices, as shown in Equation (1). The resulting emissions are categorized as shown in Equation (2).

$$E = [e^p \quad e^{p \rightarrow io} \quad e^{io}] \begin{bmatrix} C^p & 0 & 0 \\ 0 & C^{p \rightarrow io} & 0 \\ 0 & 0 & L \end{bmatrix} \begin{bmatrix} y^p \\ y^{p \rightarrow io} \\ y^{io} \end{bmatrix} \quad (1)$$

$$E = \begin{bmatrix} \text{Scope 1 and 2} & 0 & 0 \\ 0 & \text{Scope 3 (cat. 3)} & 0 \\ 0 & 0 & \text{Scope 3 (remaining cats.)} \end{bmatrix} \quad (2)$$

Equation (1) presents three sets of variables to calculate total emissions (E), each of which is divided into three elements that correspond to different scope assessments. From left to right, these sets represent emission factors, coefficient matrices, and activity data.

Looking at activity data, the vector y^p accounts for the consumption of fossil fuels and electricity made by the organization, which are expressed in physical units as required by the LCA approach. In other words, this vector covers all activities controlled by the entity responsible for direct emissions (scope 1) or indirect emissions from the generation of purchased electricity, heat, or steam (scope 2). The next element, $y^{p \rightarrow io}$, refers to the economic value of the same activities as y^p . We also express these values in monetary units to account for the rest of the indirect emissions linked to them but unaccounted for in scopes 1 and 2 (scope 3 cat. 3). The third activity vector (y^{io}) captures all operational expenses and investments controlled by the entity expressed in monetary units and not included in the $y^{p \rightarrow io}$ vector.

Coefficient matrices are required for adding the upstream indirect emissions linked to the organization's activities. The first one (C^p) is the identity matrix since scopes 1 and 2 are calculated as the product between emission coefficients (gathered in e^p as emissions per monetary unit) and the corresponding activity data (introduced in y^p). The rest of the coefficient matrices express total supply chain requirements to add the indirect activity related to the corresponding direct activity. L is the Leontief inverse, which contains the multipliers for the direct and indirect interindustry inputs required to produce one unit of output to final demand (Miller & Blair, 2009). The $C^{p \rightarrow io}$ matrix is required to include indirect emissions from the use of fossil fuels, heating or electricity that have not been previously considered in the LCA approach of scopes 1 and 2. This matrix is built by taking those columns from L that represent the sector that could substitute the activities described

in the y^p vector in case the organization needs to contract out those activities instead of doing them itself. In this study, two sectors were considered. First, the column in $C^{p \rightarrow io}$ linked to the expenditure on car fuel registered in y^p is the column from L corresponding to the “transport and storage” industry in Bogotá. Second, the column in $C^{p \rightarrow io}$ linked to electricity consumption is the column from L corresponding to the “Electricity, gas, water supply, sewerage, waste and remediation services” industry in Bogotá. Two additional columns serve to account for the trade and transport margins extracted from these expenditure items. Note that double counting problems arise as the direct emissions from these activities have already been accounted for in the conventional process analysis in scopes 1 and 2. To avoid these problems, the direct coefficient of the industry itself, represented on each column as $C^{p \rightarrow io}$, is substituted by the equivalent position of $L-I$ (where I is the identity matrix). In this way, we extract the direct emissions. Finally, the emission factors (e^p , $e^{p \rightarrow io}$ and e^{io}) correspond to the direct emissions for each type of activity data. On one hand, $e^{p \rightarrow io}$ and e^{io} are the same data under different notations: they are a diagonal matrix whose elements represent emissions per unit of output directly generated in each industry and region. They were provided by the ICIO-Bogotá structure by Gilles et al. (2021). On the other hand, e^p represents direct emissions per physical unit of fossil fuels or electricity consumed by the institution, which has been retrieved from UPME (2016b). A general perspective of all the tiered hybrid model elements is summarized in Section 1 of the Supplementary Information.

Layer decomposition

As per Peters & Hertwich (2006), the Leontief inverse ($L = (I - A)^{-1}$, where A is the technical coefficients matrix) can be reconstructed using a Taylor expansion in a standard MRIO model, as shown in Equation (3), where e stands for the emission factors matrix and y represents the final demand matrix. This fragmentation of the powers of A allows us to identify the impact E (i.e., emissions in this work) triggered on each stage or “layer” of production (Miller & Blair, 2009). I computes the 0-order layer, which measures the direct impact in the industry that completes the corresponding good; A represents the 1st-order layer, which is linked to the impact coming from direct suppliers of intermediate goods; A^2 stands for the 2nd-order layer, which shows the impact of the supplying industries that are allocated two stages before the good is ready to be consumed; and so on.

$$E = eLy = e(I - A)^{-1}y = e(I + A + A^2 + A^3 + \dots)y = eIy + eAy + eA^2y + eA^3y + \dots \quad (3)$$

In this work, we apply this decomposition to scope 3 results. One of the contributions of this paper is to split into layers not only the bulk of scope 3 emissions but also scope 3 cat. 3. Our proposal allows us to determine which stages are the emission hotspots in the whole value chain of the university's consumption of car fuel and electricity. This information can measure the degree of proximity of these emissions and what kind of actions can be taken by the organization to reduce them.

In the case of scope 3 (all cats. except cat. 3), the decomposition only requires substituting L in Equation (1) by the Taylor expansion shown in Equation (3). However, in the case of scope 3 cat. 3, the process requires the disaggregation of $C^{p \rightarrow io}$ by constructing new matrices $C^{p \rightarrow io, order}$ (one for each layer that is required), as shown in Equation (4).

$$E^{scope\ 3\ cat\ 3} = e^{p \rightarrow io} C^{p \rightarrow io, 0} y^{p \rightarrow io} + e^{p \rightarrow io} C^{p \rightarrow io, 1} y^{p \rightarrow io} + e^{p \rightarrow io} C^{p \rightarrow io, 2} y^{p \rightarrow io} + \dots \quad (4)$$

Each of the $C^{p \rightarrow io, order}$ matrices is built following a similar procedure as the original $C^{p \rightarrow io}$, but works with the powers of A instead of L . The procedure is based on taking the columns from the corresponding power of A (I for $C^{p \rightarrow io, 0}$, A for $C^{p \rightarrow io, 1}$, A^2 for $C^{p \rightarrow io, 2}$...) that represent the sector that could substitute the activities described in the y^p vector. Note that the correction to prevent double-counting must only be applied in $C^{p \rightarrow io, 0}$, in which the direct coefficients of the sector itself represented in the column are replaced by zero.

Data

The tiered hybrid model explained in the previous section requires different sources of information. First, activity data provided by the university correspond to the annual accounting records for 2018. Fuel and energy consumption in physical units have been directly added to the model to compute scopes 1 and 2, but all operational expenditures provided in monetary units (required to calculate scope 3) have been adjusted to subtract taxes and trade and transport margins. IOTs are usually expressed in basic prices, while organizations' expenditures are registered in purchasers' prices. The difference in the two kinds of prices is due to the transport, trade margins, and the taxes (net of subsidies), which are included in the purchaser's price but not in the basic price. Trade margins represent the portion of the expenditure paid to the wholesale and retail trade sectors, while transport

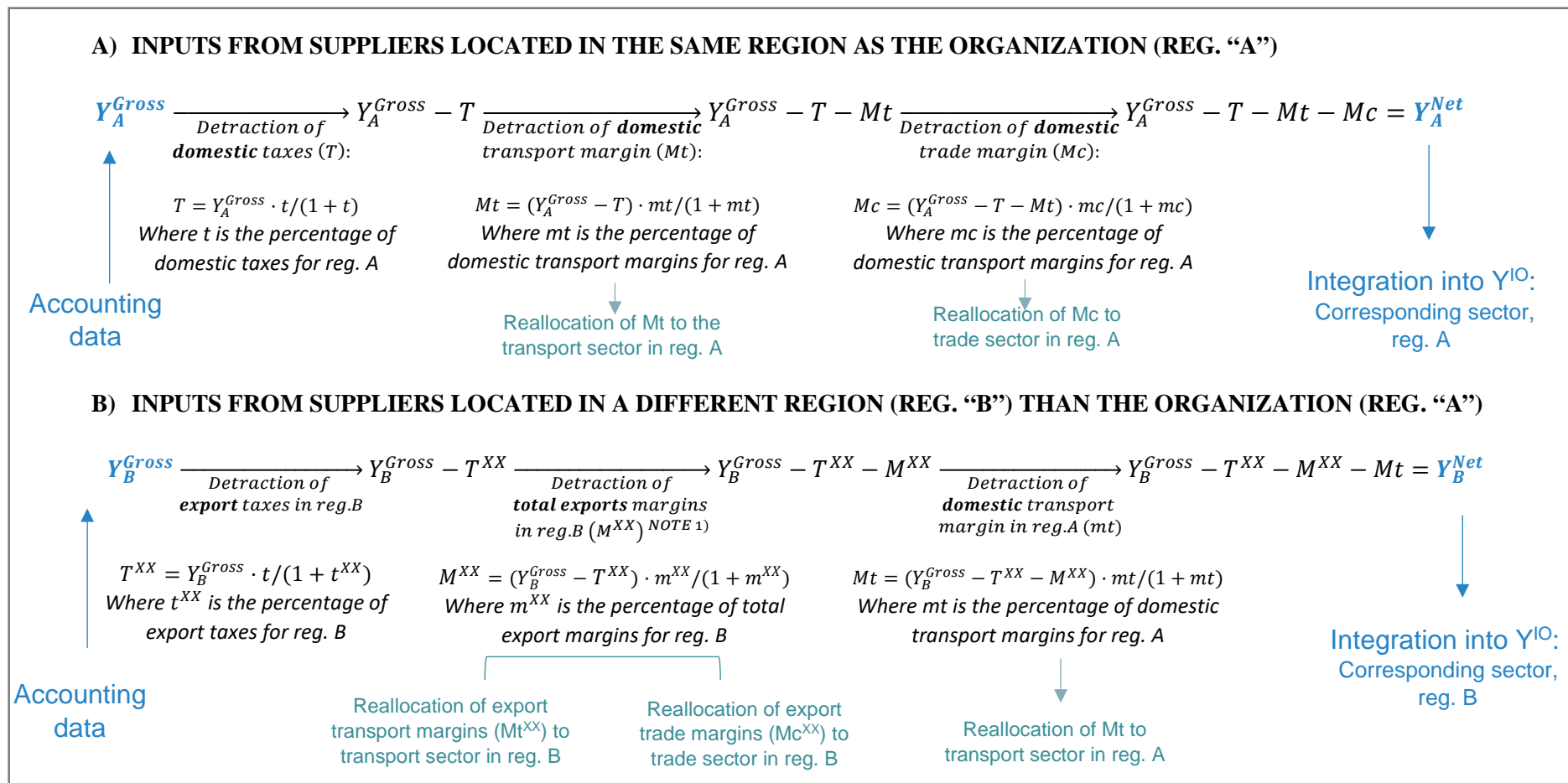
margins are those amounts paid for the transportation of a good from the producer to the consumer. The treatment of accounting data to convert the reported expenditure from purchasers' prices into basic prices is required to undertake any MRIO analysis (Eurostat, 2008; Lenzen et al., 2013; Mach et al., 2020). The adjustment process proposed herein and its underlying assumptions are described in Figure 1. The tax and margin data for each specific region were retrieved from the National Supply and Use Tables (SUTs) provided by the WIOD database (Timmer et al., 2015), except data for Colombia and Bogotá, which were extracted in deeper detail from the Colombian National Accounts (DANE, 2017).

Second, the input-output part of the hybrid model requires an MRIO table to build the coefficient matrices. In this work, $C^{p \rightarrow io}$ and L are built from the ICIO database (OECD, 2018). However, we use the extension performed by Monsalve et al. (2020), in which the IOT for the city of Bogotá (Secretaría de Hacienda de Bogotá, 2012) is nested in the ICIO database. The regional and sectoral disaggregation of this nested IOT considers 66 regions (63 countries, the city of Bogotá, the rest of Colombia, and the rest of the world) and 32 sectors in 2012 (see Section 2 in the Supplementary Information). Using a specific IOT that separates the city where the university is located from the rest of the country provides highly granular results, which may be very relevant to proposing an adequate emission-reduction strategy. This approach is also more preferable than others that are based on single-region IOTs, as highlighted by Long et al. (2020). The environmental extension of the MRIO model is estimated using CO₂ emissions data provided by the International Agency of Energy using the model proposed in Jiang et al. (2018) and Gilles et al. (2021).

Finally, the LCA part requires Colombian-specific direct emission factors per physical unit (e^p) that have been extracted from official sources (UPME, 2016a, 2016b)¹. The remaining emission factors included in $e^{p \rightarrow io}$ and e^{io} , which are expressed in emissions per monetary unit, were adapted to the Bogotá-ICIO structure by Gilles et al. (2021).

¹ The emission factors introduced in e^p are 2.01 kg CO₂/l for gasoline consumption in mobile combustion (UPME Colombia, 2016a) and 0.13 kg CO₂/kWh for electricity consumption (UPME Colombia, 2016b).

Figure 1. Taxes and margins treatment



Note 1): National SUTs in WIOD do not provide export margins, so the domestic margins provided in each supply table have been taken as a proxy for export margins for all regions except Bogotá and Colombia.
 Authors' own elaboration

Results

In 2018, the carbon footprint of EAN University accounted for 2.08 tCO₂, while the footprint of the city of Bogotá was approximately 26 MtCO₂ Gilles et al. (2021). The main results in Table 1 show that the bulk of the university's footprint is constituted of scope 3 emissions, representing up to 94% of the total footprint. Scope 2 emissions account for 6% of emissions, while scope 1 emissions comprise a negligible portion of the footprint. Usually, the higher percentage corresponds to scope 3; however, in this case, scopes 1 and 2 are significantly lower than average. The reasons behind it lie in the university's particularities; the university only owns one official car, and its buildings' electricity consumption is moderate, as the climate in Bogotá does not require excessive refrigeration or heating, which also implies that there is no expenditure for gas.

Looking at expenditure categories in scope 3, Figure 2 shows that “telecommunications and other information services” is the industry that introduces the most indirect emissions to the university's footprint (24.3%), while it is the second highest expense in the university's budget, representing 30.6% of the university expenditure in 2018. The sector with the second-highest contribution to the footprint through its indirect emissions is “other business sector services” (17.8%), which accounts for 41.4% of the university's total expenditure. The third highest industry in terms of emissions is “transportation and storage” (15.8%), for which the university expends only 2.1% of the budget. However, this expenditure corresponds mainly to international flights of the university's staff, so the high emissions intensity linked to this sector raises its contribution to the third-most impactful. The next categories in order of contribution are “taper products and printing” and “computer and electronic products” (both of which represent 11.2% of the total emissions). The purchases in these sectors constitute two places where the organization has more decision-making capacity. The university can reduce its consumption of paper products, increase the digitalization of procedures and reduce its demand for computers and electronic products by extending the lifetime of its equipment with maintenance and reparation services. In addition, although our methodological proposal uses sectoral average pollution structures, it identifies the main sectoral pollution sources. Therefore, a detailed analysis of suppliers' environmental performance could improve their selection of more sustainable partners.

Table 1. Activity data (l, kWh, €) and carbon footprint (kgCO₂) by consumption categories and scopes

Scope	Category	Inputs		CO ₂ Emissions - 2018	
		Consumption (physical units ¹)	Net Expenditure (\$)	kgCO ₂	
1.	Direct emissions			Scope 1	
1.1.	Unleaded gasoline 95 in mobile combustion	1,846.00	747.58	3,715.37	
2.	Indirect emissions			Scope 2	
2.1.	Electricity	1,016,333.00	150,892.25	132,123.29	
3.	Other indirect emissions²			Scope 3 cat 3	Scope 3 rest of cats
3.1.	1. Agriculture, forestry and fishing		3,390.79		320.22
3.2.	3. Food products, beverages and tobacco		204,035.91		46,676.50
3.3.	4. Textiles, wearing apparel, leather and related prods.		16,398.25		4,777.84
3.4.	6. Paper products and printing		912,342.30		249,257.55
3.5.	8. Chemicals and pharmaceutical products		32,070.60		11,034.67
3.6.	9. Rubber and plastic products		7,023.17		3,309.89
3.7.	12. Fabricated metal products		49,803.97		28,991.59
3.8.	13. Computer, electronic and optical products		638,739.62		248,497.26
3.9.	14. Electrical equipment		110,044.06		29,631.14
3.10.	18. Other manufacturing; repair and installation of machinery and equipment		41,750.24		10,401.77
3.11.	19. Electricity, gas, water supply, sewerage, waste and remediation services		-	³ 24,521.63	-
3.12.	21. Wholesale and retail trade; repair of motor vehicles		469,950.72		69,640.26
3.13.	22. Transportation and storage		302,331.13	⁴ 203.09	351,411.17
3.14.	23. Accommodation and food services		149,683.60		25,624.16
3.15.	24. Telecommunications and other info. serv.		4,504,487.11		538,382.20
3.16.	25. Financial and insurance activities		86,560.93		5,727.96
3.17.	27. Other business sector services		6,103,302.22		394,389.27
3.18.	29. Education		941,925.77		39,765.28
3.19.	30. Human health and social work		684.66		124.11
3.20.	Trade margins linked to scope 1+2 purchases		46.93	7.86	--
3.21.	Transport margins to scope 1+2 purchases		0.01	0.01	--
				24,732.59	2,057,962.84
				Total Scope 3	2,082,695.43

Authors own elaboration

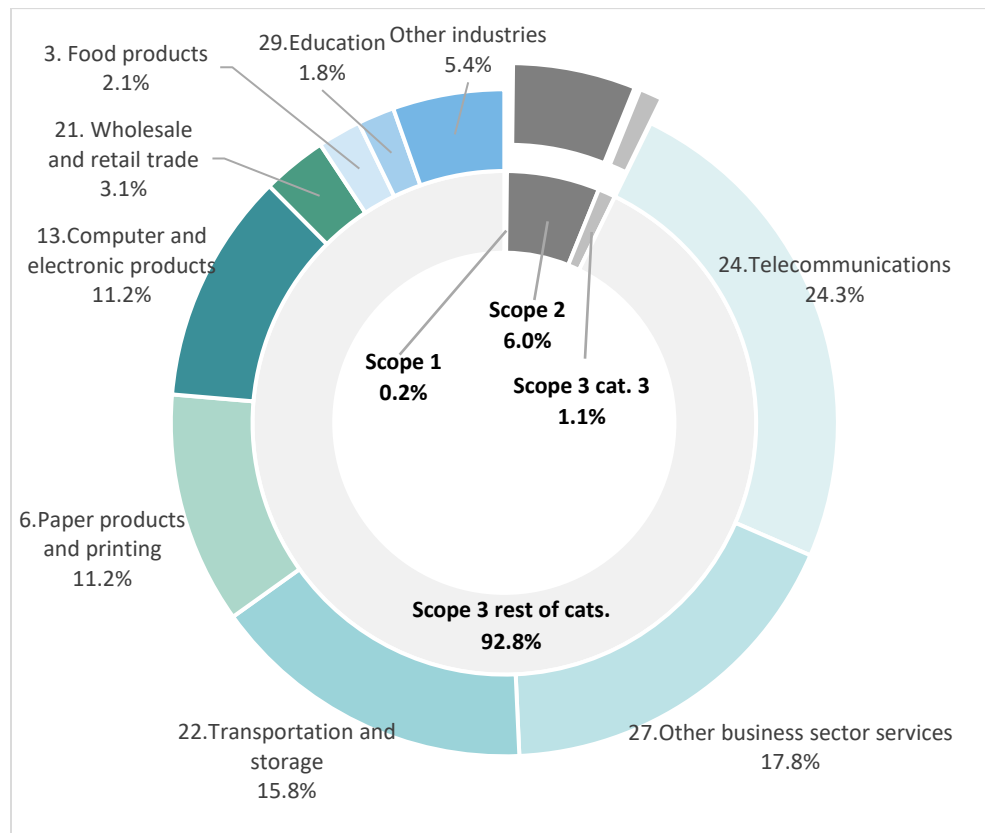
Notes to Table 1.

1. Petrol derivatives expressed in L. Natural gas and electricity expressed in kWh.
2. Net expenditure refers to gross expenditure with taxes detracted and margins reassigned.
3. These scope 3-cat 3 emissions correspond to the global expenditure on electricity shown in Row 2.1 (other indirect emissions linked to the production of the consumed electricity and not included in scope 2).
4. These scope 3-cat 3 emissions correspond to indirect emissions generated by the burn of fossil fuels for mobile combustion (vehicles owned by the university).

In relation to Equation (1), figures provided in physical units for inputs in sectors 1.1 and 2.1 compose the y^p matrix. Expenditures expressed in monetary units for inputs in Columns 1.1, 2.1, 3.20 and 3.21 compose the $y^{p \rightarrow i^0}$ matrix. Data given in monetary units for inputs 3.1. to 3.19 constitute the y^{i^0} matrix.

Full sectoral disaggregation of the ICIO_Bogotá IOT can be checked in Section 2 in SI.

Figure 2. The university's footprint by scope and input consumption category, 2018.

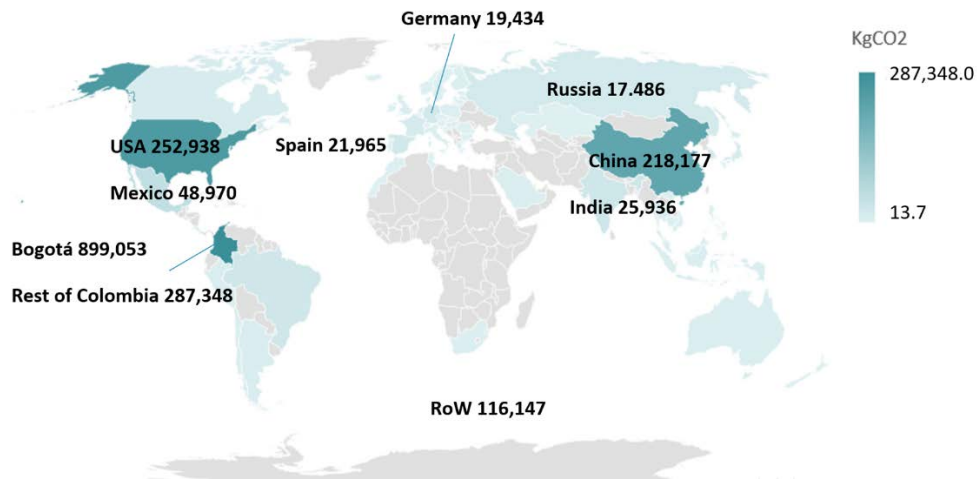


Authors' own elaboration

Note to Figure 2: full sectoral disaggregation of the ICIO_Bogotá IOT can be checked in Section 2 in SI.

Looking at the regions where the indirect emissions accounted for in scope 3 are generated (Figure 3), Bogotá and the rest of Colombia are the predominant areas, as most of the suppliers are located there (especially those providing services, whose value chain is usually less extensive than other kinds of products). However, the United States (252,938 kg CO₂) and China (227,832 kg CO₂) are close to the rest of Colombia in generating indirect emissions. These two countries account for more than 10% of emissions linked to the demand for paper products, more than 7% of emissions linked to telecommunications, and approximately 8% of the emissions for other business services. China stands out as the main contributor to the emissions behind the computers and electronic expenditure (more than 33% of the emissions in this budget category). With respect to the university's transportation demand, the United States is responsible for almost 22% of the indirect emissions, which is in part caused by staff flights to this country to attend scientific and educational events. These business travels imply that some European countries such as Spain or Germany also generate indirect emissions. This could be an interesting item for the university to evaluate in order to reduce its emissions. Encouraging virtual attendance at such events may be a relevant strategy to reduce the institution's impact. Other regions completing the top 11 (Rest of the World, Mexico, India, Brazil, and Russia) are highlighted in Figure 3.

Figure 3. University's CO₂ footprint, scope 3 (kgCO₂) by country of origin. 2018.

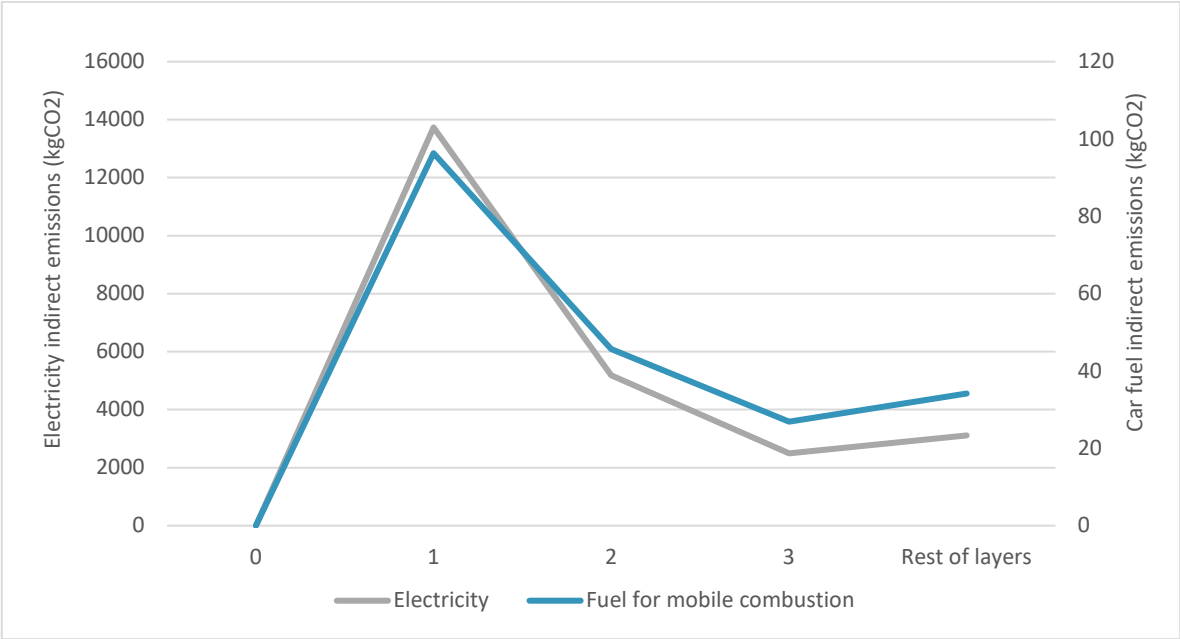


Authors' own elaboration

Note to Figure 3: RoW stands for Rest of the World. The regional details of the ICIO_Bogotá IOT can be checked in Section 2 in the SI.

The layer segmentations of both scope 3 cat. 3 and scope 3 rest of cats. are shown in Figures 4 and 5, respectively. The direct impact (layer 0) of scope 3 cat. 3 is null by construction, as it has been previously recorded in scope 1 for car fuel and scope 2 for electricity. Looking at the rest of the layers in Figure 4, although the impact peak is allocated in layer 1 for both items, the magnitude of the following layers is significant. Even though the impact coming from other layers is outside of the organization's direct control, the university has a certain capacity to reduce its footprint by selecting the immediate suppliers for these inputs. For instance, it could purchase certified electricity from green sources or substitute conventional gasoline cars with electric vehicles to avoid dependence on fossil fuels, whose origins and subsequent footprints are difficult to modify.

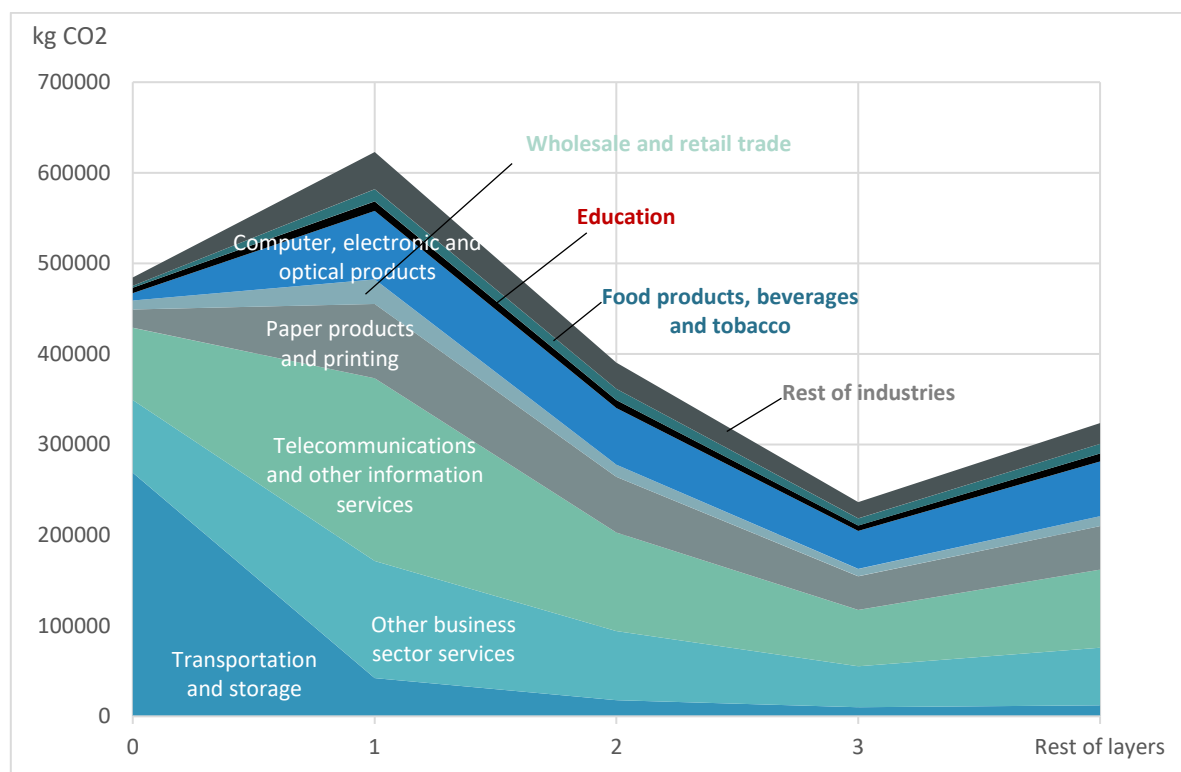
Figure 4. Scope 3 cat. 3 emissions by layers of production and expenditure item. kgCO₂. 2018.



Authors' own elaboration

The decomposition of scope 3 (excluding cat 3.) into layers reveals some interesting results. The direct impact (layer 0) is mainly composed of direct emissions from the “transportation and storage” industry. This impact is triggered, among other expenditure items, by staff business travel, which represents 46% of the university's budget devoted to the transport industry. However, when moving to the next stage of production (layer 1), indirect impacts from other sectors gain relevance while the emissions linked to the transportation industry decline. Telecommunications services, paper products, computers and electronics, or other business services constitute the bulk of layer 1 emissions, which are even higher than the direct impacts reported in layer 0. The next layers present lower emissions and similar compositions to layer 1. Therefore, the university should concentrate its efforts on reducing layer 0 and layer 1 emissions, which correspond to the stages of production that account for more emissions in scope 3 results and are the closest to the organization. In this sense, a careful selection of inputs and direct suppliers should be complemented with a tracking of, at least, the immediate providers of these suppliers.

Figure 5. Scope 3 (cat. 3 excluded) by expenditure categories and layers of production. 2018.



Authors' own elaboration

Concluding remarks

Carbon footprint reporting by organizations in Latin American countries is an incipient trend. The development of accessible and easy tools for estimating an organization's carbon footprint will ease spreading of the concept. An organization's carbon footprint will facilitate the spread of the idea and adoption of measures aligned with its country's environmental commitment. In the case of Colombia, within the Paris Agreement framework, current environmental targets pledge a 51% reduction in greenhouse gases (GHGs) by 2030. Public and private organizations are called on to move toward a greener path, and the use of carbon footprinting could allow corporations and organizations to make better choices to improve their environmental performance.

The role of educational institutions in taking the lead on environmental action in regions of rising pro-environmental behavior can be crucial. In this paper, we propose a real-case estimation of the carbon footprint of a Colombian university for a better understanding

of emissions hotspots to promote and incentivize production and consumption patterns that reduce environmental pressures. The main results show that the bulk of the emissions come from indirect impacts from the university's input in value chains, as scope 3 accounts for almost 94% of the total footprint. The disaggregation of scope 3 into industries, regions, and layers provides some key ideas for reducing the institution's impact, for instance, by selecting greener suppliers or tracking at least the next stage in the value chain of these inputs to make more sustainable decisions on suppliers and purchases.

Specifically, for the case of EAN University and given the results obtained, although scope 3 represents the highest amount of emissions, any environmentally friendly action proposed to reduce scope 1 and 2 emissions would help improve the institution's environmental performance. In this sense, the deployment of photovoltaic self-consumption installations to generate electricity would directly reduce scope 2 emissions and indirect emission reduction in scope 3 cat. 3. In addition to the energy-related measures, an increase in digitalization processes would reduce scope 3 emissions. Indeed, cloud management hides an enormous bulk of emissions (Mytton, 2020). However, the current development of decentralized cloud storage systems allows for substantial reductions in the carbon footprint (Posani, L., Paccioia, A., & Moschettini, 2018). Finally, the identification of the main sectoral emission structures and the identification of the production layer primarily involved in the generation of scope 3 emissions allow the institution to accurately evaluate their suppliers' sustainability performance. Although input-output techniques use average pollution intensity structures, which limit the degree of granularity of the model, they are a perfect tool for providing useful information to identify emissions hotspots along the value chain.

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