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Carbon footprint for the University of Castilla-La Mancha

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There is an increasing concern about the environmental performance and sustainability of firms and organizations and educational institutions are also involved. Our objective in this paper is to calculate the footprint for the Universidad de Castilla-La Mancha (UCLM) for the period 2005-2010 in order to measure its environmental impact. This is a fundamental first step to improve sustainability within this institution, as it can provide ways to reduce its environmental impact as well as decrease costs, increase environmental awareness and improve the university's image. To disentangle reasons behind emissions changes we apply a decomposition analysis to approximate the weight of reasons behind emissions changes. The calculation of the consumer responsibility through input-output methodology is assimilated to that of footprint, as this takes into account both direct and indirect emissions unlike the producer responsibility (that only includes direct emissions). As a novelty we include in the calculations of UCLM carbon footprint derived from the consumption of university workers. We think that this inclusion is necessary to make comparisons with the performance of the university in the other fields of sustainability, the economic and social one. As a matter of fact, these indirect emissions from household consumption of university workers account for two thirds of total UCLM carbon footprint. We also analyse emissions according to the industries that provide inputs to the UCLM .

Keywords: Carbon footprint, Producer responsibility, Consumer responsibility, Input-output, Procurement emissions.

Topic: 15. Environmental Input-Output Modeling.

1. Introduction

Universities are educational institutions that should lead the environmental front. Concerns about environmental responsibility require quick changes in consumption patterns to reduce emissions. The recent economic crisis has helped to reduce emissions levels, however these emissions reductions are not proved to keep over time. As it is the case for the rest of economic agents, Spanish Universities have been affected by the economic crisis, so that total expenditures have been reduced. This situation has led to a reduction in related emissions, however it is necessary to know whether this change has been due to expenditure rationalisation measures, or whether emissions will recover its previous path as universities expenditure levels are recovered. In this paper we measure emissions levels for the University of Castilla-La Mancha (UCLM from now onwards) for the period 2005-2010 and to forecast future emissions behaviour we proposed a decomposition exercise to disentangle the most important causes behind this result.

The main item in the university budget is employees' salaries, so we consider crucial to introduce emissions derived from salaries consumption decisions in a global measure of University footprint. We will work using a consumption-responsibility measure which considers 6 different gases allowed by data availability. We consider that the inclusion of the goods and services demand derived of university wages is a necessary element in a consumer responsibility measure.

We use input-output methodology instead of life cycle analysis, as input-output avoids the truncation errors that could underestimate the total environmental load. Furthermore, this methodology is completely compatible with the UCLM budget, from which we obtain a demand vector that allows us to know which products are used by the university in generating its services. This procedure allows to have a complete view of the university emissions profile and to be able to suggest specific interventions.

2. University of Castilla-La Mancha and environmental concerns

The UCLM is regional multi-campuses institution that is a Spanish medium size university, with over 28.000 registered students in 2008, placed in Castilla-La Mancha, a region located in middle Spain. It has 4 main campuses: Albacete, Ciudad Real, Cuenca and Toledo, and two minor ones, Almadén and Talavera de la Reina. Those cities are far away by distances that range from 80 to 325 kilometres, so that commuting is expensive in terms of time and money and also highly polluting.

There is not a specific footprint reduction plan in the UCLM, however there is an energy saving plan approved in 2012 that will reduce emissions. The existence of strong expenditure restrictions in the present context has led to promote saving tools based in optimising the use of already installed infrastructures, saving policy at zero cost with no investment requirements. The proposed measures have been applied at different degrees in all university buildings as a result of budget constraints due to the economic and financial crisis.

Some degrees are placed in all, or most campuses, such us Business, Law or Primary Education, while others are specific to an only location, such us Chemistry or Pharmacy. In the last case, regional students have to travel with a given frequency from their hometown to their faculty town. These trips are related to university but not included in its budget, so they would not be included in the CO2 measure.

3. Universities footprint in previous literature

Economic literature has paid special attention to institutional emissions as governments play a fundamental role in social acceptance of environmental attitudes. Universities, as key educational institutions, should lead this process, and they have been catch attention in recent literature.

In this preliminary version of the paper we review two papers on the topic for leading universities: (Larsen, Pettersen, Solli, & Hertwich, 2013) and (Ozawa-Meida, Brockway, Letten, Davies, & Fleming, 2013). (Ozawa-Meida et al., 2013) paper measures CO2 emissions for Montfort University, placed in the UK, using departmental data for the academic years from 2005-2006 to 2008-2009, using a detailed consumption-based methodology that uses a hybrid approach that combines EE-IO analysis, LCA data and primary data. They found that scope 3 emissions, indirect emissions other than those derived from the consumption of electricity, heat or steam, have the highest weight in Montfort University, and, within those, procurement emissions, being the largest pollution source.

(Larsen et al., 2013) calculates carbon footprint for the Norwegian University of Technology and Science for 2009 using an EE-IO model that hybridises energy consumption to gain accuracy. They pay special attention to the differential emissions charges by faculties and find that indirect emissions are the main element and therefore controlling university purchases is a crucial measure to limit emissions. Also the authors consider that mitigation measures must be decided with more information to provide more effective results.

The UCLM has a size comparable to the two mentioned studies, both are over 20.000, while UCLM had 28.630 registered students in 2012.

We consider that a complete footprint measurement requires detailed information of the three emission scopes. Scope three shall include all down and upstream derived indirect emissions. We include among the downstream indirect emissions thoses related to the consumption of university employees that has been purchased with university wages and salaries. This is a contribution of our paper that is not considered previously by litherature as far as we know. It is closer to the social impact measures methodology. To adequately measuring consumption related emissions we shall work with articles on households carbon footprint, among them we mention (Druckman & Jackson, 2009) or (Duarte, Mainar, & Sánchez-Chóliz, 2010). Adequately revision will be shortly included in the document.

A decomposition analysis is proposed as a tool to disentangle the weight of each of the causes behind emissions changes. The structural decomposition is applied following the line set up by (Dietzenbacher & Los, 1998) or (Xu & Dietzenbacher, 2014). Other interesting papers on the topic have also been reviewed, such us (Alcántara & Padilla, 2009) or (Michel, 2013). Adequately revision will be shortly included in the document.

Main conclusion is that of the emissions reducing efforts do not depend on university's decisions, but in university employees hands, since labour costs cover around 55% of university expenditures.

4. Methodology

We use the usual GHG measure, carbon footprint, calculated through an Environmental Extended Input-Output model (EEIO). Since primary data are not available, it is not possible to apply a hybrid methodology as in Ozawa-Meida et al.

Aggregation levels and classification is different for the three uses data sources, so that a matching effort is required (comentar los grupos más problemáticos). Labour cost have the higher weight among all expenditure chapters, and the decision about how to use this income is a household one. We consider that expenditure for university employees families is distributed among different expenditure groups in the same proportion that any other household in the region. Therefore we distribute wages and salaries among all sectors using consumption data from the National Statistical Institute (INE in its Spanish acronym).

We are interested in measuring the consumer responsibility of the UCLM, since the institution generates emissions indirectly when consuming other sectors' goods and services. To build the consumer responsibility measure we can start by the more usual producer responsibility measure. This measure is the one considered in most international agreements such as Kyoto. The producer responsibility can be calculated from the following expression (Cadarso, López, Gómez, & Tobarra, 2010, 2012):

$$PR = \hat{e}(I - A^d)^{-1} \hat{y}^d = \varepsilon^d (\hat{y}^r + \hat{y}^x) \qquad (1)$$

where $\hat{e}$ is a diagonal matrix of emissions by unit produced by each sector of activity available at national level, I is the identity matrix, A^d is the technical coefficients matrix available at regional level, and $\hat{y}^d$ is the diagonal matrix that captures that usually considers final demand met by domestic production and in our analysis of UCLM emissions it refers to total UCLM expenditures. Elements in matrix $\hat{e}$ are obtained by dividing all six greenhouse gases measured in CO2 tonnes equivalents per activity sector (E), by its effective production. We can then calculate the emission multiplier that quantifies direct and indirect emissions by domestic final demand $\varepsilon^d = \hat{e}(I - A^d)^{-1}$. In input-output methodology the matrix of final domestic production can be decomposed in two elements: exports ($\hat{y}^x$) and domestic demand ($\hat{y}^r$). In our case the last element is not considered $\hat{y}^d = \hat{y}^r$, emissions generated in the production of goods that are to be consumed overseas, however this step is not necessary for the UCLM since it does not export its services.

Equation (1) associates the university expenditure data, categorised as input-output products, with its respective sectoral emissions an technology, so that it is possible to classify emissions changes according to four possible causes:

- Changes in expenditure structure: as expenditure moves from more (less) polluting items to less (more) ones the total amount of emissions is expected to be reduced (increased).
- Changes in technology: As technology required to produce goods and services consumed by the university changes, as sectors increase or reduced their dependence

with other sectors with a different emissions rate ones the total amount of emissions is expected to change.

- Changes in sectoral emissions patterns: As sectors that satisfy university purchases use cleaner technologies, university carbon footprint will be reduced.
- And finally, more general of all, changes in total university expenditure.

Consumer responsibility can be calculated by introducing some changes to the previous expression, such as adding emissions linked to the production of goods imported by the institution either as intermediate or final goods. The consumer responsibility can be calculated from the following expression:

$$CR = \left[\hat{e}(I - A^d)^{-1}\hat{y}^r\right] + \left[\hat{e}(I - A^t)^{-1}[\mathrm{A^m}\left(\mathrm{I - A^d}\right)^{-1}\hat{\mathrm{y}}^{\mathrm{r}} + \hat{\mathrm{y}}^{\mathrm{m}}]\right] \quad (2)$$

were $\mathrm{A^m}$ is the technical coefficient matrix for goods imported and $\hat{y}^m$ the matrix of university imported purchases. The first element, containing $\hat{y}^r$, accounts for emissions generated domestically when producing goods and services purchased by the university from domestic intermediate inputs. The second element has two components, the one linked to $\hat{y}^r$, accounts for emissions generated domestically when producing goods and services purchased by the university from imported intermediate inputs, while finally the element linked to $\hat{y}^m$ accounts for emissions generated when producing imported goods and services purchased by the university. Expression (2) assumes that the production technology and pollution in countries producing universities imported purchases are the same, is the Domestic Technology Assumption (DTA)[1].

There is one item in the budget that deserves special attention. Most of the university expenditure cannot be classified as final demand, but as income provided to their workers that will use it for the acquisition of goods and services, generating emissions in a later stage, following the trend of economic impact studies. We also consider emissions of this last stage as part of scope 3 emissions. To measure them we must apply the *CR* methodology to calculate emissions related to households consumption, with an expression equivalent to (2) but where the final demand vector considers total expenditures by sector for families with a total expenditure given by the university budget chapter I amount. We call this concept Income derived consumer responsibility and can be expressed as:

$$IDCR = \left[\hat{e}(I - A^d)^{-1}\hat{m}^r\right] + \left[\hat{e}(I - A^t)^{-1}[\mathrm{A^m}\left(\mathrm{I - A^d}\right)^{-1}\hat{m}^{\mathrm{r}} + \hat{m}^{\mathrm{m}}]\right] \quad (3)$$

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[1] This assumption, common in literature ((Munksgaard & Pedersen, 2001; Peters & Hertwich, 2006; Sánchez-Chóliz & Duarte, 2004), does not acknowledge the possibility of reducing CO2 consumption by changing purchases provider, since environmental efficiency is expected to differ among countries. On the other hand, see (Wiedmann, Lenzen, Turner, & Barrett, 2007) for a theoretical review of single-region and multi-region input-output models for the assessment of environmental impacts of trade and (Andrew, Peters, & Lennox, 2009) for a quantification of the errors introduced by various approximations of the full Multi-regional input-output, for national carbon footprint accounting. These last authors conclude that the difference when measuring the ecological footprint using a DTA model or an MRIO for the Spanish economy in 2001 is only 1%, but they do not consider the possible differences by industries.

were $\hat{m}$ is expenditure en final consumption for households that can be satisfy by the three sources commented in expression (2). For university employees families expenditure consumption is distributed following the regional consumption pattern that is given by the Households Budget Survey provided by INE that considers 116 consumption items. Those must be aggregated to 63 groups to be comparable with our calculation in expressions (2). We can express the final equation for the Extended UCLM Footprint (EFP) as:

$$EFP = CR + IDCR \qquad (4)$$

We are interested in following the extended UCLM carbon footprint over time, so the measure will be calculated for the period 2005-2010. We shall also disentangle the reasons behind possible changes in the measure, where the two elemental possibilities are changes in the amount or distribution of expenditure, changes in the production technology in relation to input-output relationships and changes in the emissions coefficients. This methodology will be adequately explained in coming versions of the paper.

In terms of the GHG accounting framework, this methodology allows the calculation of scope1, all direct GHG emissions, 2, Indirect GHG emissions from consumption of purchased electricity, heat or steam, and 3 emissions, other indirect emissions, such us those derived from any other good or service purchased by the institution, i.e. materials and fuels, , outsourced activities, waste disposal, etc. Scope 3 downstream emissions is contemplated as emissions generated by university employees when consuming from their income.

The consumer responsibility measure is calculated for the period 2005-2010. Data availability explains this period limitations. Data sources are combined as follows. Expenditure data, are taken from the university budget. Since the University does not give detailed information of imported purchases, distribution among imported and domestic final consumption, y^m an y^r, *is* calculated considering that proportion of imported final consumption is similar to the regional one, these regional data are available for the period 2005 to 2008.[2] Intermediate inputs information is taken from regional input-output accounts, available for the period 2005-2008. Finally, sectoral emissions data are required however these data are not available at regional level. National emission coefficients have therefore been calculated using total emissions and total production for a national-sectoral aggregation level. Emissions data provided by the INE GHG other than CO2 are translated to its OC2 equivalent measure.

About aggregation level, matrices size has been kept to 68 sectors, the regional tables aggregation level since this is the most used source. Aggregation adjustments have been applied to the national emissions and product data. Aggregation levels have changed for both series. Emissions data differentiate 63 sectors from 2008, and 35 prior to that date. Total production data differentiate 103 sectors for 2008 and 2009, and 118 prior to that date.

By using university expenditure data we account for travel expenditure paid by university, such us intra-campuses trips for administrative staff or teachers, trips made and paid by students for academic reasons are not considered.

The second stage is to apply an structural decomposition to the emissions calculation over time. Methodology for the

[2] Input-output regional data are only available until 2008, so 2008 data are projected to 2009 and 2010, therefore that the implicit hypothesis is that neither technology nor domestic/imported consumption relationship have changed significantly for those two years.

5. Main variables

UCLM Emissions can be calculated from budget data. UCLM budget classifies expenditure in three main groups, divided in 9 different chapters. Group 1 is Current expenditures, Group 2 is Capital investment, and Group 3 is financial expenditures. Personal expenditure is the most important item over the whole period, while investment has modified its weight importantly over the period. Table 1 shows the university budget in general groups for 2005 and 2010.

Table 1. UCLM budget for 2005 and 2010.

	2005		2010	
Expenditure chapters	**Expenditure in constant €**	**%**	**Expenditure in constant €**	**%**
I. Personnel costs	97699524	55,43	135747129	55,61
II. Currents assets and services expenses	41044979	23,29	50309991	20,61
III. Financial expenditures	1307908	0,74	342172	0,14
IV. Current transfers	2725835	1,55	3835637	1,57
VI. Real investments	25484923	14,46	46010662	18,85
VII. Capital transfers				
VIII. Changes in financial assets	240000	0,14	240000	0,10
IX. Changes in financial liabilities	7741533	4,39	7601000	3,11
TOTAL	176244702		244086591	

Source: UCLM

Although this is a rough comparison, since real euros are considered, it is possible to observe that expenditure distribution has not change much over the period, while total expenditure has changed noticeably for some items. Expenditure in absolute terms has increased mainly for Real Investments (over 80%), Current transfers (over 40%) and also in personnel expenditures (almost 39%), while it has been reduced drastically for Financial expenditures (around 74%) (figures not shown). At a subsequent version of the paper a more disaggregated expenditure budget will be available.

6. Results

Some very recent changes in data availability due to our main data source improvement, INE, and new other data released by university have invalidated previous, less disaggregated, results of the paper. New calculation are being made and they will be shortly available. At the moment and as a first draft we show here a very brief summary of previous general results for 2012.

The broad emissions measure for 2012 is 313.230,566 CO_2 kilotons, that amounts to the 0.02% of the total national emissions and 0.32% of the total regional ones.

From those emission, sectoral analysis allows to identify the sectors that are main responsibles for UCLM emissions. Table 2 includes information on them.

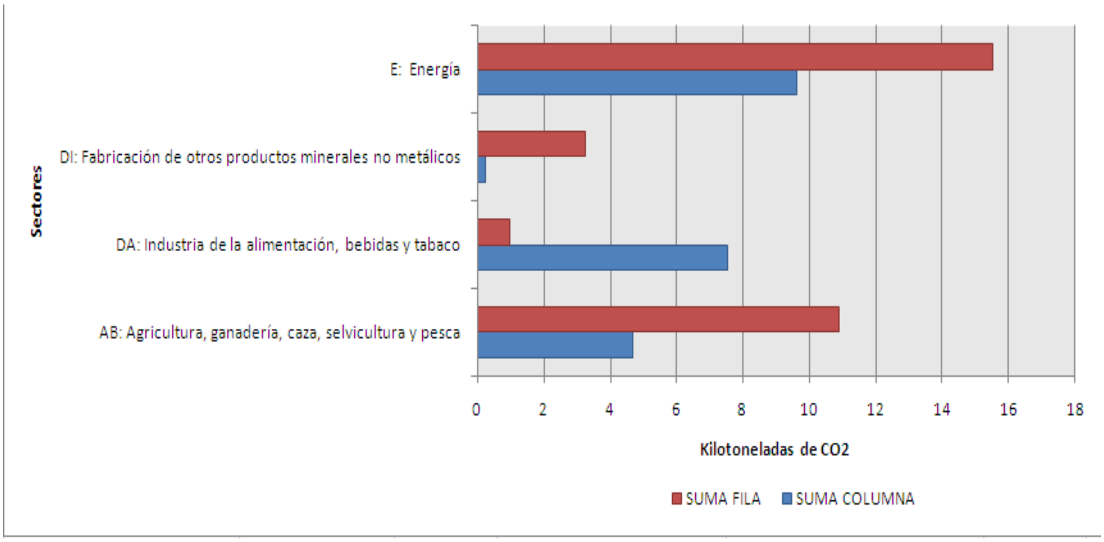
Table 2. Main responsible sectors for UCLM 2012 emissions.

	Emissions (CO2 eqv)	% Total CLM Emisiones
Energy	8.008,88	0,40
Agriculture, Hunting, Forestry and Fishing	3.877,61	0,19
Other Non-Metallic Mineral	3.840,17	0,19
Food, Beverages and Tobacco	435,89	0,02
Total	**16.162,54**	**0,80**

Source: Own results

Analysing these sectors deeper we found the different weight of emissions per column or row, as it is shown in Figure 1.

Figure 1. UCLM c arbon footprint by columns and rows.



As commented at the beginning of this section new results can be now calculated using more disaggregated data for either the emissions coefficient, that goes from 33 to 62 sectors, households consumption sectors that go from 68 to 116 groups, university budget items, that the university has committed to provide in a still undetermined figure. New improved results will be shortly provided.

7. Conclusions

Such an important emissions level due to procurement leads to a difficult situation, since university does not have a direct control on those kind of emissions and, at the same time, it offers interesting opportunities for emissions reduction. A clear identification of polluting goods and services, so that the university can choose with full information its purchases characteristics, is essential. The burden of an eco-tax, that allows to identify more polluting goods as more expensive ones and discourages its consumption, or the use of eco-labels, that provide enough information on emissions embodied in goods, are two of the possible options.

Bibliography

Alcántara, V., & Padilla, E. (2009). Input–output subsystems and pollution: An application to the service sector and CO2 emissions in Spain. *Ecological Economics, 68*(3), 905-914. doi: http://dx.doi.org/10.1016/j.ecolecon.2008.07.010

Andrew, R., Peters, G. P., & Lennox, J. (2009). APPROXIMATION AND REGIONAL AGGREGATION IN MULTI-REGIONAL INPUT–OUTPUT ANALYSIS FOR NATIONAL CARBON FOOTPRINT ACCOUNTING. *Economic Systems Research, 21*(3), 311-335. doi: 10.1080/09535310903541751

Cadarso, M.-Á., López, L.-A., Gómez, N., & Tobarra, M.-Á. (2010). CO2 emissions of international freight transport and offshoring: Measurement and allocation. *Ecological Economics, 69*(8), 1682-1694. doi: http://dx.doi.org/10.1016/j.ecolecon.2010.03.019

Cadarso, M.-Á., López, L.-A., Gómez, N., & Tobarra, M.-Á. (2012). International trade and shared environmental responsibility by sector. An application to the Spanish economy. *Ecological Economics, 83*(0), 221-235. doi: http://dx.doi.org/10.1016/j.ecolecon.2012.05.009

Dietzenbacher, E., & Los, B. (1998). Structural decomposition techniques: Sense and sensitivity. *Economic Systems Research, 10*(4), 307-323.

Druckman, A., & Jackson, T. (2009). The carbon footprint of UK households 1990–2004: A socio-economically disaggregated, quasi-multi-regional input–output model. *Ecological Economics, 68*(7), 2066-2077. doi: http://dx.doi.org/10.1016/j.ecolecon.2009.01.013

Duarte, R., Mainar, A., & Sánchez-Chóliz, J. (2010). The impact of household consumption patterns on emissions in Spain. *Energy Economics, 32*(1), 176-185. doi: http://dx.doi.org/10.1016/j.eneco.2009.08.007

Larsen, H. N., Pettersen, J., Solli, C., & Hertwich, E. G. (2013). Investigating the Carbon Footprint of a University - The case of NTNU. *Journal of Cleaner Production, 48*(0), 39-47. doi: http://dx.doi.org/10.1016/j.jclepro.2011.10.007

Michel, B. (2013). Does offshoring contribute to reducing domestic air emissions? Evidence from Belgian manufacturing. *Ecological Economics, 95*(0), 73-82. doi: http://dx.doi.org/10.1016/j.ecolecon.2013.08.005

Munksgaard, J., & Pedersen, K. A. (2001). CO2 accounts for open economies: producer or consumer responsibility? *Energy Policy, 29*(4), 327-334. doi: http://dx.doi.org/10.1016/S0301-4215(00)00120-8

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., & Fleming, P. (2013). Measuring carbon performance in a UK University through a consumption-based carbon footprint: De Montfort University case study. *Journal of Cleaner Production, 56*(0), 185-198. doi: http://dx.doi.org/10.1016/j.jclepro.2011.09.028

Peters, G. P., & Hertwich, E. G. (2006). The Importance of Imports for Household Environmental Impacts. *Journal of Industrial Ecology, 10*(3), 89-109. doi: 10.1162/jiec.2006.10.3.89

Sánchez-Chóliz, J., & Duarte, R. (2004). CO2 emissions embodied in international trade: evidence for Spain. *Energy Policy, 32*(18), 1999-2005. doi: http://dx.doi.org/10.1016/S0301-4215(03)00199-X

Wiedmann, T., Lenzen, M., Turner, K., & Barrett, J. (2007). Examining the global environmental impact of regional consumption activities — Part 2: Review of input–output models for the assessment of environmental impacts embodied in trade. *Ecological Economics, 61*(1), 15-26. doi: http://dx.doi.org/10.1016/j.ecolecon.2006.12.003

Xu, Y., & Dietzenbacher, E. (2014). A structural decomposition analysis of the emissions embodied in trade. *Ecological Economics, 101*(0), 10-20. doi: http://dx.doi.org/10.1016/j.ecolecon.2014.02.015