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The materiality of the immaterial. Services sectors and CO_2 emissions in Uruguay

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Abstract

This paper analyzes the carbon dioxide emissions of the services sectors subsystem of Uruguay in 2004. Services, with the exception of transport, are often considered intangible because of their low level of direct emissions. However, the provision of services requires inputs produced by other sectors, including several highly material-intensive sectors.

Through input–output analysis we investigate the relationship between the services subsystem and the rest of the economy as regards carbon dioxide emissions. This approach allows us to study the importance of the set of services branches as a unit in the economic structure as well as to analyze in detail the relationship between the branches. The results depict that services' direct emissions are the main component, as a consequence of transport related sectors. However, the pollution that the services subsystem makes the rest of the economy produce is very significant, and it is almost all explained by non-transport related sectors. This analysis is useful for determining the sectors in which mitigation policies are more effective, and whether they would be better tackled through technical improvements and better practices or through demand policies.

Keywords: input–output analysis, subsystems, carbon dioxide emissions, services.

1. Introduction

Services were wrongly considered intangible and unusable to create value like the industrial sectors by Adam Smith (Smith, 1776). In modern times, this deficient characterization has been expressed in different ways. Services have been considered non-capital intensive, with low productivity growth and an inability to be economic driving forces because their output can only be sold locally. This leads to them being perceived as "environment-friendly" and even "non-material" activities (with the exception of transport related sectors) (Gallouj and Djellal, 2010).[1] This notion is supported by the fact that services do not produce material goods and they are not very important direct polluters. Hence, the emission intensities per unit of output of non-transport services are lower than the emission intensities of other sectors of the economy (Suh, 2006). This has led to services industries being widely ignored when designing mitigation policies (Rosenblum et al., 2000; Gadrey, 2010).

However, the provision of services is developed through interactions with customers who are reached through a combination of service operations, conditioning and travel (Fourcroy et al.; 2012). Each of these elements requires direct energy consumption (and hence pollution), but also requires other sectors to consume raw materials and energy, and to pollute when taking part in these interactions. Gadrey (2010) shows that countries where the services sector accounts for a larger share of the economy consume more energy and have larger ecological footprints than countries where the services sectors are less developed. These arguments contradict the false perception that services sectors are non-material sectors, as shown by several authors (Rosenblum et al., 2000; Suh, 2006; Nansai et al., 2007; Alcántara and Padilla, 2009; Fourcroy et al., 2012).

Services sectors played a very important role in the Uruguayan economy in reference to value added and employment. These sectors increased from 50% to 72% of total Uruguayan GDP between 1870 and 2010 (Bonino et al., 2012). The Uruguayan economic performance shows a very irregular path in the long run (Figure 1). Phases of rapid growth were followed by deep crises, explained as a cyclical pattern correlated with volatility of terms of trade, world demand and international capital flows (Bértola, 2008). During this period three phases of development patterns are identified (Bértola

[1] Fourcroy et al. (2012) presented an excellent review of the evolution of the concept of non-materiality of services.

and Porcile, 2000; Bonino et al., 2012). However, the composition of the service sector during this development stages changed (Bértola, 2008). Between the last decades of the 19th century and the 1930s the first globalization took place, following and outward-oriented trade strategy. The services sector focused mainly on commerce, transport and traditional state bureaucracy during this period. Later on, the import substitution industrialization model came up between the 1930s and the 1970s. The main components of the service sector during this period where health care, education and social services. Since the 1970s the Uruguayan development model follows again an outward-oriented trade strategy, exporting mainly primary products. Military expenditure, tourism and finance became the main components of services sectors during this period.

[Figure 1]

The greenhouse gas (GHG) emissions from the Uruguayan productive structure reached 36,773 ktons (in carbon dioxide equivalent units) in 2004.[2] The Uruguayan National Climate Change Response Plan (NCCRP) (MVOTMA, 2010a) exposes the strategic lines of action for GHG mitigation. The NCCRP calls to improve the practices in the primary sectors, transport and waste management, and to improving energy efficiency and reducing energy consumption. Despite carbon dioxide emissions only representing 16.6% of the total Uruguayan GHGs (methane, carbon dioxide, and nitrous oxide) in 2004, half of these emissions are directly related to the services sectors. The NCCRP mitigation lines of action explicitly consider transport related sectors as well as improvements in the lighting systems of services branches. They also consider energy efficiency improvements in general terms. However, while technical improvements and better practices would be effective in diminishing emissions from direct polluter sectors, other sectors may be indirect polluters when demanding inputs to polluting sectors. In this case, demand policies in indirect polluting sectors (e.g. eco-labeling, or input substitution) can be implemented for complementing mitigation policies in direct polluters. This is the case of many of the branches of services. Except the transport related activities, all the other activities of the services subsystem are non-direct polluters. If these sectors are important in pollution terms, the decomposition of the

[2] Accounting for CO_2, CH_4 and N_2O. The sectoral allocation of emissions is elaborated by the authors based on DNETEN (2008) and MVOTMA (2010b), following the Eurostat (2009) methodology. An appendix detailing this process is available upon request.

services subsystem multipliers will allow the orientation of the design of complementary mitigation policies. In an economy highly supported in services, as has been shown to be the Uruguayan economy, this is a very important and useful task for correctly designing carbon dioxide mitigation policies to complement technical improvements and better practices in direct polluting sectors.

The present paper analyzes the carbon dioxide emissions of the services sector subsystem of Uruguay in 2004. This is the first empirical analysis on the indirect carbon dioxide emissions from services sector in a small open economy heavily based on services. Given the significance of services in the national economy, this analysis would have different implications than in the case of developed industrialized economies, where mitigation policies can be also implemented in industrial sectors. Input–output analysis extended to carbon dioxide emissions helps to determine if a sector (or a group of sectors) pollutes itself for satisfying its own final demand, or as a consequence of the inputs demanded by the rest of the economy. Disentangling this allows to identify which kind of policy measures are better and in which sectors mitigation policies will be more effective. We combine two decomposition methodologies. First, we apply multiplicative decomposition developed by Pyatt and Round (1979) and later applied to interregional multipliers by Sonis and Hewings (1993) and Dietzenbacher (2002) to analyze the relationship between each subsystem and the rest of the economy. This methodology captures the full circular flow of transactions for production in the economy. Fritz et al. (1998) is the only example of an environmental application of this method to disentangle the relationship between polluting and non-polluting sectors. Second, we apply additive decomposition to analyze the relationship within the subsystem itself. This allows a more intuitive and easier interpretation of the relationships within the subsystem sectors. Multiplier decomposition can be interpreted as systems that produce “pollution by means of pollution” (Alcántara, 1995), as an environmentally extended application of Sraffa’s (1972) “production of commodities by means of commodities.”

The paper is organized as follows: Section 2 presents the methodology; Section 3 provides the empirical results; Section 4 discusses the results and their policy implications; and the final section concludes.

2. Methodology

Input–output analysis is a tool that has been widely used for measuring structural interdependence since Hirschman (1958). Environmentally extended input–output analysis allows for a more complete understanding of the relationship between the economy and the material flows, which is essential for fully understanding environmental problems and the policy design to solve them (Hoekstra, 2005). Sometimes it is relevant to focus on some specific sectors, and study their relationship with the environment with greater complexity, without losing their linkages with the entire production system (Alcántara, 1995). If we consider a system of industries in which each produces a different commodity as defined in input–output analysis, "such a system can be subdivided into as many parts as there are commodities in its net product, in such a way that each part forms a smaller self-replacing system, the net product of which consists of only one kind of commodity. These parts we shall call 'subsystems'" (Sraffa, 1960, p. 89). Thus, subsystem analysis allows the study of the structure of each of the industries involved in the economic system, while it increases the explanatory power of the traditional approach of key sector analysis, providing a greater level of disaggregation of the linkages between those branches within the subsystem and between the subsystem branches and the rest of the economy (Alcántara and Padilla, 2009; Navarro and Alcántara, 2010). The environmentally extended input–output subsystem analysis allows to analyze how a given group of sectors make the rest of the economy to pollute or consume natural resources for satisfying their final demand.

Subsystem analysis of the relationship between the productive structure and the environment was first proposed by Alcántara (1995), who applied it to sulfur dioxide, nitrogen oxides and volatile organic compound emissions in Spain in 1985 through additive decomposition into five components of the emissions generated by each industry: i) scale; ii) feedback; iii) own; iv) spillover; and v) spillover of the rest of the economy. Alternative additive decompositions were employed to analyze the environmental impact in water resources pollution in Aragon, Spain, in 1995 by Sánchez-Chóliz and Duarte (2003), carbon dioxide emissions in the services subsystem in Spain in 2000 by Alcántara and Padilla (2009), methane emissions in the agricultural and food industry in Catalonia, Spain, in 2001 by Navarro and Alcántara (2010) and six greenhouse gases in Ireland in 2005 by Llop and Tol (2012). Multiplicative decomposition derived from the Miyazawa (1966, 1968, 1971) multipliers was employed by Fritz et al. (1998) to analyze how the subsystem of non-polluting sectors influenced the emissions of air polluting sectors in the Chicago region through a structural decomposition analysis between 1975 and 2010.

Alcántara and Padilla (2009) was the only previous work focused in services subsystem carbon dioxide emissions. Unlike them, we employ a multiplicative decomposition for disentangling the effects between the subsystem of interest and the rest of the economy, similar to Fritz et al. (1998). Multiplicative decomposition isolates better than additive decomposition the internal interrelationships of the subsystem from the relationship of the subsystem with the rest of the economy. This is because the internal component is not a function of the Leontief inverse (which includes in each element indirect effects from the rest of the economy). We employ a multiplicative decomposition to disentangle the internal linkages of the services subsystem from its linkages with the rest of the economy. In this way, three main components are distinguished (Figure 2).[3] The *internal component* depicts the emissions of the services subsystem to satisfy its final demand. The internal component shows both the emissions produced by the sectors of the services subsystem when producing products to satisfy their own final demand directly and the emissions when producing inputs demanded by the sectors of the services subsystem, also to satisfy their own final demand. The *feedback component* depicts those emissions produced by the sectors of the services subsystem to provide inputs to sectors outside the services subsystem, but which are used by them to provide inputs to the services subsystem sectors. The *spillover component*, accounts for those emissions produced by sectors not belonging to the services subsystem to provide inputs to sectors of the services subsystem to satisfy their final demand.

[Figure 2]

However, the internal component of the services subsystem deserves to be analyzed in greater detail to allow a better understanding of the relationships between the sectors within the subsystem. We decompose these internal relationships through additive decomposition, because it allows a more intuitive interpretation when considering

[3] The methodology is formally developed in Appendix I.

sectors one by one (after isolating the subsystem's internal interrelationships from those with the rest of the economy). From this, we split the internal component emissions into four components: a) those emissions that a sector of the services subsystem directly produces to satisfy its final demand (*internal scale component*); b) the pollution generated by a sector of the services subsystem when producing inputs purchased by itself (*internal own component*); c) the pollution generated by a sector of the services subsystem when producing inputs that are used by other sectors of the same subsystem to provide inputs to it (*internal feedback component*); and d) the emissions that a sector from the services subsystem makes other sectors of the same subsystem generate in their productive processes to provide inputs for its final demand (*internal spillover component*).

The method employed analyses emissions from a production-based perspective. This means that we do not consider emissions embodied in imported inputs. The production-based approach is defined from a territorial perspective that allows to develop domestic mitigation analysis and to guide national policy design. A consumption-based approach requires complex information that is not available for Uruguay for recent years. To alleviate this requirement, the domestic technology structure assumption for computing factors embodied in imported commodities has been widely employed in the literature. However, this has been demonstrated to be an implausible assumption for determining the emissions balance (Lenzen et al., 2004).[4]

3. The services subsystem and carbon dioxide emissions in Uruguay

The analysis is conducted using the 2005 Uruguayan input–output matrix constructed by Terra et al. (2009). This matrix was constructed in the benchmark of a Red Mercosur–Food and Agricultural Organization (FAO) agreement for technical assistance to the Agriculture, Livestock and Fishing Ministry, with detailed national accounts data provided by the Uruguayan Central Bank (BCU). It is split into 56 branches at basic prices. We constructed the carbon dioxide emissions accounts from

[4] Uruguay is a small economy based on agro-industrial exports. This makes the domestic technology structure assumption to be implausible in this case, because it is not possible to produce its imports domestically. Andrew et al. (2009), using data for 2001 based on an input–output matrix for 1997, show that Uruguay is one of the countries for which the domestic technology structure assumption gives the most biased results for carbon dioxide multipliers. This is a consequence of the high weight of clean energy sources in its energy matrix, which differs from the technology generally employed to produce its imports. Because of this, a consumption-based approach under the domestic technology structure assumption is neither realistic nor useful for this case study.

the 2004 greenhouse gas inventory that the Ministry of Housing, Land Use Planning and Environment reports to the Intergovernmental Panel for Climate Change (MVOTMA, 2010a). The greenhouse gas inventory classifies emissions in reference to their processes of origin. To allocate the sectoral emissions we follow the Eurostat (2009) methodology, and we employ secondary sources like the reports of the National Energy and Nuclear Technology Direction (DNETN, 2008), which detail the structure of net and used energy consumption for the year 2006.[5]

The total carbon dioxide emissions in Uruguay in 2004 reached 8,675 ktons, 70% of which came from the whole productive sectors (primary, manufacturing, and services sectors) (MVOTMA, 2010b).[6] The services subsystem consists of 13 sectors that represented 52.5% of the Uruguayan total output in 2005.[7] Its direct emissions reached 2,783.7 ktons, while the total emissions (direct and indirect emissions required to satisfy its final demand) according to input–output analysis were 2,862 ktons in 2004 (45.7% and 46.9% of the total CO_2 emissions, respectively) (Table 1).

[Table 1]

The direct and total emissions of the services subsystem are quite similar in absolute terms. On the one hand, despite the sectors Land transport; transport via pipelines (46); and Water and air transport (47) are the two main contributors to the subsystem's direct emissions, their contribution to the subsystem's total emissions to satisfy its final demand is significantly smaller. This is explained because a significant share of these sectors pollution is produced when providing inputs to the rest of the economy. On the other hand, the contribution to the total emissions significantly rises in relation to direct emissions for Wholesale and retail trade; repair of motor vehicles and motorcycles sectors (44); Hotels and restaurants (45); and Public administration and defense; compulsory social security (52). For the other sectors the variation is very small. Because of the trade-off between direct and indirect emissions in the contribution of

[5] A methodological annex detailing the sectoral allocation of emissions is available upon request.
[6] It considers international bunkers and biomass burning CO_2 emissions.
[7] In the existing literature, services activities are defined through both a positive and a residual definition. For the residual definition services are all the activities that are not manufacturing or agricultural activities, while for the positive definition services are branches that meet specific characteristics that distinguish them from other economic activities (Fourcroy et al., 2012). For the Uruguayan case, and the level of aggregation of the input–output matrix employed, the two perspectives are highly coincident.

these sectors it is worth decomposing the total emissions in order to be better able to distinguish the best channels for mitigation policies.

Table 1 also depicts which part of the total emissions services subsystem is produced for satisfying its exports or its domestic consumption. The share of the emissions produced for satisfying their exports (35.1%) is slightly lower than the pollution for producing exports of the whole economy (39.3%). In addition, 94.5% of the emissions of the services subsystem consequence of the export are produced by the transport related sectors. Furthermore, the transport related sectors share in total emissions of the service subsystem for satisfying its domestic consumption represents 47.4%. This is a reasonable result, given that services final demand includes many branches that are usually oriented to the domestic consumption (e.g. Hotel and restaurants, Education, Health and social work, Real estate activities, Sewage and refuse disposal).

Table 2 shows the decomposition of the services subsystem multipliers. The internal component explains most carbon dioxide emissions of this subsystem (77.8%). This means that most of the total emissions (directly plus indirectly) produced by the services subsystem for satisfying its final demand are emitted by itself. The significance of the internal component is mainly explained by the internal scale component (63.4% of the total emissions of the services subsystem). The internal scale component accounts for the emissions directly produced by the polluting sector for satisfying its own final demand. These emissions are mainly produced by the two transport related sectors (46 and 47), which are the main direct polluters. Both sectors allocate more than 60% of their production to the final demand.

[Table 2]

Less relevant, but still significant, is the weight of the internal spillover component (11.7% of the total emissions of the services subsystem). The internal spillover component represents the emissions that a sector from the service subsystem makes other sectors of the same subsystem generate in their productive processes to provide inputs to satisfy its final demand. The main contributor to this component is the Wholesale and retail trade; repair of motor vehicles and motorcycles sector (44) (58.2%), while the rest of the emissions are spread among the other sectors. This is because it pulls the transport related sectors (46 and 47) to pollute as a consequence of the inputs that sector 44 demands from them.

Also very significant is the spillover component. This component depicts the emissions that the subsystem makes the rest of the economy to produce to meet its final demand. That is, this component is the one that sheds light on the indirect emissions not accounted for when the services are considered to be non-material. It represents 19.7% of the overall emissions of the services subsystem and 9.3% of the emissions of the whole economy..

[Figure 3]

[Figure 4]

Figure 3 shows the most relevant linkages in terms of carbon dioxide emissions between the services subsystem and the rest of the economy, and the linkages between sectors belonging to the rest of the economy. This allows to characterize the path of the most relevant indirect emissions in the spillover to the rest of the economy. It is shown that the significance of the non-transport related sectors in this component is mainly due to their demand to the Electricity, gas and water supply (42) sector, but also, in a more indirect way, to the emissions from the Refined petroleum (33) sector (Table A2.1 in Appendix 2 depicts the detail of the spillover component). This result clearly shows that services sectors demand is also based on the materiality of the rest of the economy. Additionally, the services sectors not related to transport activities account for 90% of the subsystem spillover component. This is different in the internal own component, in which almost all the emissions were consequence of transport related activities.

Figure 4 shows the production layer in which the total emissions of each of the sectors of the services subsystem are produced. The emissions are produced in very early stages of the productive process in all the sectors. While almost all emissions are produced in the first stage in the transport related sectors, in the non-transport related sectors the emissions are mainly produced in an indirect way. As explained, the internal spillover is consequence of the input provision by the transport related sectors. Moreover, all the services sectors that are important in the spillover component are relevant mainly because of their direct or indirect electricity demand. A very interesting result is the emissions of the Other non-metallic products (38) sector consequence of the spillover of the Real estate activities (50) sector. These emissions are consequence of the cement production for house building that reaches the final demand through this sector. These emissions are more indirect than the ones that are consequence of electricity demand, given that the Real estate activities (38) sector does not demand cement itself. This is an important result where environmentally extended input–output analysis helps to shed light, and that could not be easily quantified without this approach. The spillover effects of the Wholesale and retail trade; repair of motor vehicles and motorcycles (44) sector on the Refined petroleum (33) sector are also relevant because of retail oil. Moreover, the Hotels and restaurants (45) sector has a relevant share in the spillover component not only as a consequence of its electricity demand, but also because of the emissions produced when demanding inputs to the Distilling, rectifying and blending of spirits (23) sector. Thus, this analysis not only helps to identify where energy efficiency measures, as identified in the NCCRP priority action lines, are more effective, but also to identify other spillover effects of higher order, than can be tackled by encouraging input substitution or final demand policies. Finally, the feedback component is almost negligible.

4. Discussion and policy implications

The above results show that both the internal own and spillover components as well as the spillover to the rest of the economy are significant. This means that the pollution of the services subsystem is important not only because of its internal transactions, but also because it pulls other sectors of the economy to pollute. The significance of the non-transport related sectors indirect emissions must be highlighted. This refutes the non-material perception of services sectors, in line with Rosenblum (2000), Suh (2006), Nansai et al. (2007), Alcántara and Padilla (2009), Gadrey (2010) and Fourcroy et al. (2012). Rosenblum et al. (2000) and Suh (2006) also confirm that the spillover component of services sectors is an important issue to be considered, but their results are not directly comparable with our analysis. The importance of the spillover component for Uruguay is smaller than in the analysis of Alcántara and Padilla (2009) for the Spanish economy in 2000. This is an interesting result, given that both countries are considered to be in different stages of development in the moment of the analysis. While the Spanish economy passed through the typical agricultural-industrial-services stages of development, the presence of the industrial sectors has been very weak in the Uruguayan case (see Figure 1 in the Introduction section). This makes the former to show a higher spillover component as a consequence of the domestic demand of intermediate inputs from the services sectors to the rest of the economy. The spillover component of the Uruguayan non-transport related services sectors is mainly explained by energy demand to develop wholesale trade, tourism and public administration activities. While, these activities are also relevant in the Spanish case, that country was experiencing a construction boom during the time that the study by Alcántara and Padilla (2009) was performed. This explains the much higher importance of Real estate activities sector in their study, as a consequence of the straight link of this sector with the construction and cement production activities (both of which are significant in carbon dioxide emissions terms). Given that the share of the services sectors in the Uruguayan economy is increasing, it is important to analyze the relevant carbon dioxide mitigation policies in light of the above results. Rosenblum et al. (2000) list four kinds of measures that can act on services sectors to influence their environmental performance: i) influencing suppliers to provide more environmentally conscious products and services, ii) reduce resource use of inputs by improving their energy efficiency and cutting business travel, iii) developing consumers' education programs about the relative merits of the different products that are offered, and iv) reduce the resource use of consumers by substituting more environmentally beneficial services or activities to reduce the resource use by the final demand. In this way, to encourage services labeling and process certification would be an effective policy for providing consumers with better information and helping them to change their consumption mix by less harmless products. Moreover, it is very useful to distinguish where the indirect emissions are produced, in order to induce the firms to substitute their polluting inputs by cleaner ones where possible. This is important for helping companies to certificate their productive processes. Moreover, this would also help to conduct technical improvements and best practices in reference to energy consumption that would diminish emissions from the spillover component.

Moreover, technological improvement and best practices are effective policies to mitigate the carbon dioxide emissions from direct polluting sectors, mitigating not only the emissions produced by the internal scale component, but also the indirect emissions that the rest of the economy makes the direct polluters to produce. These measures would be very effective for carbon dioxide mitigation from transport related sectors. This point shows the importance of the reduction of energy consumption in these sectors, which is identified as a priority line of action in the NCCRP. Nevertheless, it must be considered that to achieve an accurate design for a mitigation program, the rebound effects should be adequately taken into account.

The above analysis is a useful guideline for the efficient design of specific measures aligned with the NCCRP priority lines of action. It allows the determination of both the sectors in which mitigation policies are more effective and the kinds of measures that are more appropriate in each case.

This type of policies could help to mitigate indirect emissions from the rest of the economy in order to complement the measures implemented in direct polluters. They would also contribute to mitigate the emissions that are consequence of the internal spillover component.

5. Conclusions

The share of the services sectors subsystem in the Uruguayan economy grew from 50% to 61% of total GDP between 1870 and 1990. Moreover, this share significantly increased the last 20 years, amounting to 72% of total Uruguayan GDP in 2010 (Bonino et al., 2012). Services sectors have been considered as "non-material" because they are not extremely important direct polluters and have lower emission intensities per unit of output than other sectors of the economy (except in the case of transport sectors). However, service provision can indirectly impact on other sectors' pollution, because their production is needed for this provision. Gadrey (2010) showed that countries where the services sectors amount for a larger share of the economy consume more energy and have larger ecological footprints than countries where the services sectors are less developed. Given the significance of the services sectors in the Uruguayan economy, its environmental performance must be seriously considered.

In the present paper, we analyze the carbon dioxide emissions of the services sectors subsystem of Uruguay in 2004. We combine two methods: multiplicative decomposition to analyze the relationship of the subsystem with the rest of the economy, and additive decomposition for the study of the linkages within the subsystem. This approach allows us to study the significance of the subsystem as a whole in the economic structure as well as to analyze in detail the relationship between each of the subsystem's branches.

The non-material perception of the service sectors is refuted. The results show that while transport related services are significant because of their direct emissions, non-transport related services are also important because of the pollution indirectly produced for providing inputs to them. From this analysis, it is suggested not only to encourage technological improvements and better practices in direct polluters, but also the relevance to complement these measures with final demand policies on indirect polluting sectors.

Further research in this subject would follow two lines. First, it would be important to extend a similar analysis employing a multi-regional input-output (MRIO) matrix. This would allow to analyze the spillover of these a priori non-material sectors not only to the rest of the economy but also to the rest of the world. This would be a very important source of emissions in a country like Uruguay that imports all the raw oil to be refined, and many other inputs from non-clean processes. Unfortunately a MRIO database allowing to look at the Uruguayan intersectoral linkages in detail is not yet available. Second, it would be very important to conduct an analysis with different scenario settings of the services subsystem, and look for differences in the spillover component. Services linkages with the rest of the economy can be based in different structural relationships. This would allow to see feasible structural transformations in the Uruguayan services subsystem and its environmental consequences.

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Appendix 1: Methodology

The Leontief model identity, $\boldsymbol{x'} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y'} = \boldsymbol{Ly'}$, denotes the relationship between the total output levels ($\boldsymbol{x'}$) required in an economy to hold a final demand column vector ($\boldsymbol{y'}$) through the inverse Leontief matrix (or matrix of coefficients of direct and indirect requirements per unit of final demand).[8] Matrix $\boldsymbol{A}$ is the Leontief domestic inputs coefficients matrix, the elements, a_{ij}, of which depict the weight of how much sector j purchases from sector i in relation to the total sector j production. To isolate the effects of subsystem s this model can be rewritten in a partitioned way as:

(1) $$\begin{pmatrix}\boldsymbol{x^{s\prime}}\\ \boldsymbol{x^{r\prime}}\end{pmatrix} = \left(\begin{bmatrix}\boldsymbol{I}_{s\times s} & \boldsymbol{0}\\ \boldsymbol{0} & \boldsymbol{I}_{r\times r}\end{bmatrix} - \begin{bmatrix}\boldsymbol{A}_{ss} & \boldsymbol{A}_{sr}\\ \boldsymbol{A}_{rs} & \boldsymbol{A}_{rr}\end{bmatrix}\right)^{-1}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{y^{r\prime}}\end{pmatrix} = \begin{bmatrix}\boldsymbol{L}_{ss} & \boldsymbol{L}_{sr}\\ \boldsymbol{L}_{rs} & \boldsymbol{L}_{rr}\end{bmatrix}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{y^{r\prime}}\end{pmatrix}$$

Following Pyatt and Round (1979), Round (1985, 2001), Sonis and Hewings (1993) and Dietzenbacher (2002), the inverse Leontief matrix, $\boldsymbol{L}$, can be decomposed as follows:

(2) $$\begin{pmatrix}\boldsymbol{x^{s\prime}}\\ \boldsymbol{x^{r\prime}}\end{pmatrix} = \begin{bmatrix}\boldsymbol{F}_{s} & \boldsymbol{0}\\ \boldsymbol{0} & \boldsymbol{F}_{r}\end{bmatrix} \times \begin{bmatrix}\boldsymbol{I}_{s\times s} & \boldsymbol{S}_{sr}\\ \boldsymbol{S}_{rs} & \boldsymbol{I}_{r\times r}\end{bmatrix} \times \begin{bmatrix}\boldsymbol{M}_{s} & \boldsymbol{0}\\ \boldsymbol{0} & \boldsymbol{M}_{r}\end{bmatrix}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{y^{r\prime}}\end{pmatrix}$$
$$= \begin{bmatrix}\boldsymbol{F}_{s}\boldsymbol{M}_{s} & \boldsymbol{F}_{s}\boldsymbol{S}_{sr}\boldsymbol{M}_{r}\\ \boldsymbol{F}_{r}\boldsymbol{S}_{rs}\boldsymbol{M}_{s} & \boldsymbol{F}_{r}\boldsymbol{M}_{r}\end{bmatrix}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{y^{r\prime}}\end{pmatrix}$$

where:

$\boldsymbol{M}_{s} = (\boldsymbol{I} - \boldsymbol{A}_{ss})^{-1}$ and $\boldsymbol{M}_{r} = (\boldsymbol{I} - \boldsymbol{A}_{rr})^{-1}$

$\boldsymbol{S}_{sr} = (\boldsymbol{I} - \boldsymbol{A}_{ss})^{-1}\boldsymbol{A}_{sr}$ and $\boldsymbol{S}_{rs} = (\boldsymbol{I} - \boldsymbol{A}_{rr})^{-1}\boldsymbol{A}_{rs}$

$\boldsymbol{F}_{s} = [\boldsymbol{I} - (\boldsymbol{I} - \boldsymbol{A}_{ss})^{-1}\boldsymbol{A}_{sr}(\boldsymbol{I} - \boldsymbol{A}_{rr})^{-1}\boldsymbol{A}_{rs}]^{-1} = [\boldsymbol{I} - \boldsymbol{S}_{sr}\boldsymbol{S}_{rs}]^{-1}$

$\boldsymbol{F}_{r} = [\boldsymbol{I} - (\boldsymbol{I} - \boldsymbol{A}_{rr})^{-1}\boldsymbol{A}_{rs}(\boldsymbol{I} - \boldsymbol{A}_{ss})^{-1}\boldsymbol{A}_{sr}]^{-1} = [\boldsymbol{I} - \boldsymbol{S}_{rs}\boldsymbol{S}_{sr}]^{-1}$

The production needed to obtain the total output of subsystem s can be isolated assuming $\boldsymbol{y}^{r} = \boldsymbol{0}$, such that:

(3) $$\begin{pmatrix}\boldsymbol{x}_{s}^{s\prime}\\ \boldsymbol{x}_{s}^{r\prime}\end{pmatrix} = \begin{bmatrix}\boldsymbol{L}_{ss} & \boldsymbol{L}_{sr}\\ \boldsymbol{L}_{rs} & \boldsymbol{L}_{rr}\end{bmatrix}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{0}\end{pmatrix} = \begin{bmatrix}\boldsymbol{F}_{s}\boldsymbol{M}_{s} & \boldsymbol{F}_{s}\boldsymbol{S}_{sr}\boldsymbol{M}_{r}\\ \boldsymbol{F}_{r}\boldsymbol{S}_{rs}\boldsymbol{M}_{s} & \boldsymbol{F}_{r}\boldsymbol{M}_{r}\end{bmatrix}\begin{pmatrix}\boldsymbol{y^{s\prime}}\\ \boldsymbol{0}\end{pmatrix}$$

[8] In this paper, elements in **bold** denote vectors and matrices (lower case and upper case, respectively), while the scalars are expressed in plain text. In turn, the ^ symbol over a vector element refers to a diagonal matrix composed of the specified vector.

where $\boldsymbol{x}_s^s$ is the production of subsystem *s* to satisfy its final demand and $\boldsymbol{x}_s^r$ is the production of the rest of the economy to be employed as input by subsystem *s*. Premultiplying (3) by $\boldsymbol{u}$, a summation row vector, the total production of the economy that is needed for the final demand of subsystem *s* is obtained:

$$(4) \qquad \boldsymbol{u}_{1\times n}\begin{pmatrix}\boldsymbol{x}_s^{s\,\prime}\\ \boldsymbol{x}_s^{r\,\prime}\end{pmatrix} = \boldsymbol{u}_{1\times s}\boldsymbol{L}_{ss}\boldsymbol{y}^{s\,\prime} + \boldsymbol{u}_{1\times r}\boldsymbol{L}_{rs}\boldsymbol{y}^{s\,\prime} = \boldsymbol{u}_{1\times s}\boldsymbol{F}_s\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime} + \boldsymbol{u}_{1\times r}\boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}$$

where the first term accounts for both the internal transactions of subsystem *s* to satisfy its final demand and a *feedback* component, which accounts for the sales of subsystem *s* to the rest of the economy that are employed for providing inputs to the sectors of subsystem *s*. The second term accounts for those sales from the rest of the economy employed by subsystem *s* as inputs to satisfy its final demand. The first component can be decomposed, adding and subtracting $\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}$, such that:

$$(5) \qquad \boldsymbol{u}_{1\times n}\begin{pmatrix}\boldsymbol{x}_s^{s\,\prime}\\ \boldsymbol{x}_s^{r\,\prime}\end{pmatrix} = \boldsymbol{u}_{1\times s}\boldsymbol{F}_s\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime} + \boldsymbol{u}_{1\times s}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime} - \boldsymbol{u}_{1\times s}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime} + \boldsymbol{u}_{1\times r}\boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}$$

$$= \underbrace{\boldsymbol{u}_{1\times s}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{internal\ component} + \underbrace{\boldsymbol{u}_{1\times s}[\boldsymbol{F}_s - \boldsymbol{I}]\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{feedback\ component} + \underbrace{\boldsymbol{u}_{1\times r}\boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{spillover\ component}$$

The expression above decomposes the total production that is needed to fulfill the total final demand of subsystem *s*.

The model above can be easily extended to any environmental dimension to take into account the environmental impact. We define $\boldsymbol{c}_{nx1}{}' = \begin{pmatrix}c_1\\ \vdots\\ c_n\end{pmatrix}$, a vector of coefficients that relates every sector to a particular environmental dimension (either resource use or pollution), such that $\boldsymbol{c}'\boldsymbol{x} = E$, where $\boldsymbol{x}$ is the vector of sector output and E is a scalar that denotes the total resource use or pollution generation. Henceforth, $\boldsymbol{c}$ is defined as the carbon dioxide emissions' intensity vector. In this way, the direct emissions coefficient of sector *j* can be defined as $c_j = {}^{e_j}\!/_{x_j}$, where e_j indicates sector *j*'s direct emissions. The emissions coefficients vector can be expressed in a partitioned way, as before, such that $\boldsymbol{c}_{nx1}{}' = \begin{pmatrix} \boldsymbol{c}^{s\,\prime} \\ \boldsymbol{c}^{r\,\prime} \end{pmatrix}$, where $\boldsymbol{c}^{s}$ are the coefficients of the direct emission of the sectors of subsystem s. Premultiplying (1) by a diagonal matrix constructed from vector $\boldsymbol{c}$, the model can be transformed as:

$$
\begin{aligned}
(6) \qquad \boldsymbol{e}' &= \hat{\boldsymbol{c}}\boldsymbol{x} = \hat{\boldsymbol{c}}\boldsymbol{L}\boldsymbol{y}' \\
&= \begin{pmatrix} \widehat{\boldsymbol{c}^s} & \boldsymbol{0} \\ \boldsymbol{0} & \widehat{\boldsymbol{c}^r} \end{pmatrix} \begin{bmatrix} \boldsymbol{L}_{ss} & \boldsymbol{L}_{sr} \\ \boldsymbol{L}_{rs} & \boldsymbol{L}_{rr} \end{bmatrix} \begin{pmatrix} \boldsymbol{y}^{s\,\prime} \\ \boldsymbol{y}^{r\,\prime} \end{pmatrix} \\
&= \begin{pmatrix} \widehat{\boldsymbol{c}^s} & \boldsymbol{0} \\ \boldsymbol{0} & \widehat{\boldsymbol{c}^r} \end{pmatrix} \begin{bmatrix} \boldsymbol{F}_s & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{F}_r \end{bmatrix} \times \begin{bmatrix} \boldsymbol{I} & \boldsymbol{S}_{sr} \\ \boldsymbol{S}_{rs} & \boldsymbol{I} \end{bmatrix} \times \begin{bmatrix} \boldsymbol{M}_s & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{M}_r \end{bmatrix} \begin{pmatrix} \boldsymbol{y}^{s\,\prime} \\ \boldsymbol{y}^{r\,\prime} \end{pmatrix} \\
&= \begin{pmatrix} \widehat{\boldsymbol{c}^s} & \boldsymbol{0} \\ \boldsymbol{0} & \widehat{\boldsymbol{c}^r} \end{pmatrix} \begin{bmatrix} \boldsymbol{F}_s\boldsymbol{M}_s & \boldsymbol{F}_s\boldsymbol{S}_{sr}\boldsymbol{M}_r \\ \boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s & \boldsymbol{F}_r\boldsymbol{M}_r \end{bmatrix} \begin{pmatrix} \boldsymbol{y}^{s\,\prime} \\ \boldsymbol{y}^{r\,\prime} \end{pmatrix}
\end{aligned}
$$

where $\boldsymbol{e}_{n\times 1}{}'$ is a column vector, the elements of which are $e_j \; \forall \, j = 1, \dots, n$. Again, to analyze the role of subsystem s in the total emissions, $\boldsymbol{y}^r = 0$ is assumed, such that:

$$
(7) \qquad \begin{bmatrix} \boldsymbol{e}_{\boldsymbol{s}}^{s\prime} \\ \boldsymbol{e}_{\boldsymbol{r}}^{s\prime} \end{bmatrix} = \begin{bmatrix} \widehat{\boldsymbol{c}^s} & \boldsymbol{0} \\ \boldsymbol{0} & \widehat{\boldsymbol{c}^r} \end{bmatrix} \begin{bmatrix} \boldsymbol{F}_s\boldsymbol{M}_s & \boldsymbol{F}_s\boldsymbol{S}_{sr}\boldsymbol{M}_r \\ \boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s & \boldsymbol{F}_r\boldsymbol{M}_r \end{bmatrix} \begin{pmatrix} \boldsymbol{y}^{s\,\prime} \\ \boldsymbol{0} \end{pmatrix}
$$

where $\boldsymbol{e}_{\boldsymbol{s}}^{s}$ are those emissions coming from the production processes of subsystem s to satisfy its own final demand and $\boldsymbol{e}_{\boldsymbol{r}}^{s}$ is the pollution from the rest of the sectors during their production processes to provide subsystem s with the inputs it needs to satisfy its final demand. Similar to equation (5), by premultiplying (7) by a unitary vector $\boldsymbol{u}_{nx1}$, we obtain the total emissions of subsystem s (E^s):

$$
\begin{aligned}
(8) \qquad E^s &= \boldsymbol{c}^s\boldsymbol{F}_s\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime} + \boldsymbol{c}^r\boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s\boldsymbol{y}^{s\prime} = \\
&\underbrace{\boldsymbol{c}^s\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{internal\ component} + \underbrace{\boldsymbol{c}^s[\boldsymbol{F}_s - \boldsymbol{I}]\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{feedback\ component} + \underbrace{\boldsymbol{c}^r\boldsymbol{F}_r\boldsymbol{S}_{rs}\boldsymbol{M}_s\boldsymbol{y}^{s\,\prime}}_{spillover\ component}
\end{aligned}
$$

It is also relevant to split those components between the sectors of subsystem s. For this purpose, each component can be rewritten, diagonalizing the last vector, such that:

(9) $\boldsymbol{\mu}_s^{internal} = \boldsymbol{c}^s\boldsymbol{M}_s\widehat{\boldsymbol{y}}^{\boldsymbol{s}}$

depicts the contribution of each subsystem sector to the subsystem internal component. The internal component shows both the emissions produced by subsystem *s* when producing products to satisfy its own final demand directly and the emissions when producing inputs demanded by itself, also to satisfy its own final demand.

Equation (9) can be split additively to distinguish between: a) those emissions that a sector of subsystem *s* directly produces to satisfy its final demand (*internal scale component*); b) the pollution of a sector of subsystem *s* when producing inputs purchased by itself (*internal own component*); c) the pollution generated by a sector of subsystem *s* when producing inputs that are used by other sectors of the same subsystem to provide inputs to it (*internal feedback component*); and d) the emissions that a sector from subsystem *s* makes other sectors of the same subsystem generate in their productive processes to provide inputs for its final demand (*internal spillover component*).

For this, matrix $\boldsymbol{M}_s$ can be written as $\boldsymbol{M}_s = \boldsymbol{M}_s^D + \boldsymbol{M}_s^O$, where $\boldsymbol{M}_s^D$ is a diagonal $s_x s$ matrix that contains the main diagonal of matrix $\boldsymbol{M}_s$, while matrix $\boldsymbol{M}_s^O$ is equal to matrix $\boldsymbol{M}_s$, but with null values in its main diagonal. The technical coefficients matrix of subsystem *s* can be rewritten in the same way, such that $\boldsymbol{A}_{ss} = \boldsymbol{A}_{ss}^D + \boldsymbol{A}_{ss}^O$. From above, $\boldsymbol{M}_s$ can be expressed as $\boldsymbol{M}_s = \boldsymbol{A}_{ss}^D \boldsymbol{M}_s^D + \boldsymbol{A}_{ss}^O \boldsymbol{M}_s + \boldsymbol{A}_{ss}^D \boldsymbol{M}_s^O + \boldsymbol{I}$.[9]

(9a) $\boldsymbol{\mu}_s^{internal-scale} = \boldsymbol{c}^s \hat{\boldsymbol{y}}^s$

(9b) $\boldsymbol{\mu}_s^{internal-own} = \boldsymbol{c}^s \boldsymbol{A}_{ss}^D \boldsymbol{M}_s^D \hat{\boldsymbol{y}}^s$

(9c) $\boldsymbol{\mu}_s^{internal-feedback} = \boldsymbol{c}^s \boldsymbol{A}_{ss}^D \boldsymbol{M}_s^O \hat{\boldsymbol{y}}^s$

(9d) $\boldsymbol{\mu}_s^{internal-spillover} = \boldsymbol{c}^s \boldsymbol{A}_{ss} \boldsymbol{M}_s^O \hat{\boldsymbol{y}}^s$

In addition,

(10) $\boldsymbol{\mu}_s^{feedback} = \boldsymbol{c}^s (\boldsymbol{F}_s - \boldsymbol{I})\, \boldsymbol{M}_s \hat{\boldsymbol{y}}^s$

shows the contribution of each subsystem sector to the subsystem feedback component. It depicts those emissions produced by the sectors of subsystem *s* to provide inputs to

[9] $\boldsymbol{M}_s = [\boldsymbol{M}_s - \boldsymbol{I}] + \boldsymbol{I} = \boldsymbol{A}_{ss}\boldsymbol{M}_s + \boldsymbol{I} = (\boldsymbol{A}_{ss}^D + \boldsymbol{A}_{ss}^O)(\boldsymbol{M}_s^D + \boldsymbol{M}_s^O) + \boldsymbol{I} = \boldsymbol{A}_{ss}^D \boldsymbol{M}_s^D + \boldsymbol{A}_{ss}^O \boldsymbol{M}_s^D + \boldsymbol{A}_{ss} \boldsymbol{M}_s^O + \boldsymbol{I}$

sectors outside the subsystem, but which are used by them to provide inputs to subsystem sectors. Finally,

(11) $$\boldsymbol{\mu}_s^{spillover} = \boldsymbol{c}^r \boldsymbol{F}_r \boldsymbol{S}_{rs} \boldsymbol{M}_s \widehat{\boldsymbol{y}}^s$$

depicts the contribution of each subsystem sector to the subsystem spillover component. The spillover component accounts for those emissions produced by sectors not belonging to subsystem *s* to provide inputs to sectors of subsystem *s* to satisfy their final demand.

Appendix 2:

Table A2.1: Services subsystem CO_2 spillover on the Rest of the Economy (CO_2 Ktons)

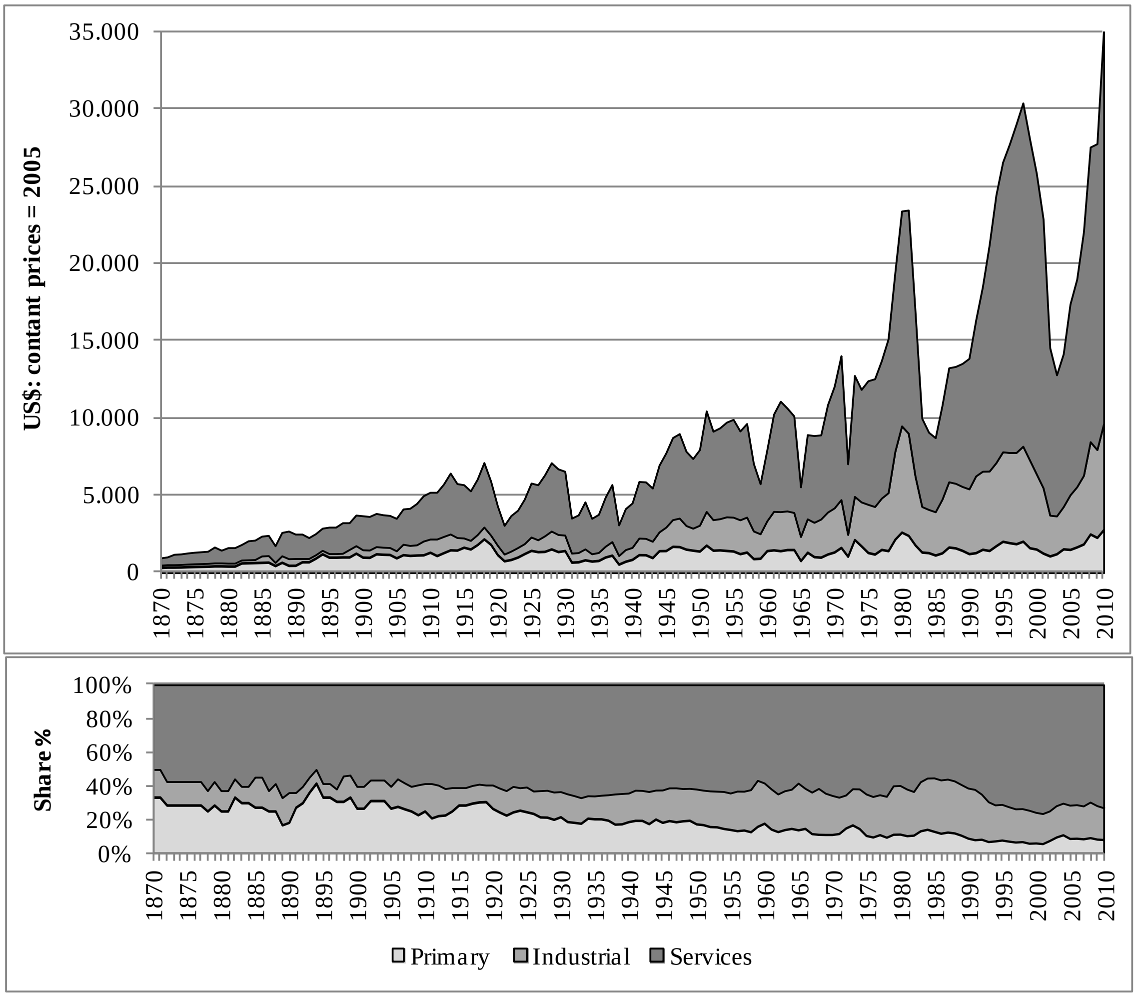
Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	Spillover component
44	0.27	0.47	0.02	0.08	0.28	0.29	0.04	0.06	2.25	0.29	0.22	0.00	0.00	0.00	0.24	0.06	0.02	0.32	0.12	0.20	0.20	0.01	0.31	0.00	0.47	0.33	0.19	0.04	0.00	1.16	10.35	2.48	19.01	0.01	0.01	0.82	0.10	9.85	1.07	0.02	0.00	43.74	0.13	95.53
45	1.86	2.21	0.51	1.48	1.50	2.41	0.25	0.07	4.42	0.11	5.26	0.00	0.00	0.00	3.78	1.49	0.06	2.26	3.07	2.63	7.82	0.35	12.21	0.00	0.08	0.11	0.05	0.01	0.00	0.80	2.69	0.47	8.23	0.02	0.03	0.45	0.05	4.78	0.30	0.00	0.00	23.97	0.05	95.79
46	0.03	0.23	0.00	0.01	0.17	0.04	0.00	0.01	1.41	0.04	0.04	0.00	0.00	0.00	0.04	0.01	0.00	0.06	0.01	0.02	0.02	0.00	0.04	0.00	0.04	0.03	0.03	0.00	0.00	0.13	0.93	0.29	36.36	0.00	0.00	0.08	0.02	0.80	0.21	0.01	0.00	3.83	0.01	44.97
47	0.02	0.31	0.00	0.01	0.02	0.03	0.00	0.01	0.05	0.02	0.04	0.00	0.00	0.00	0.04	0.01	0.00	0.03	0.04	0.02	0.04	0.00	0.06	0.00	0.03	0.02	0.02	0.00	0.00	0.56	1.26	0.32	6.37	0.00	0.00	0.07	0.00	0.72	0.10	0.01	0.00	4.18	0.01	14.44
48	0.00	0.02	0.00	0.00	0.01	0.01	0.00	0.01	0.04	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.02	0.00	0.03	0.04	0.02	0.00	0.00	0.32	2.08	0.75	2.21	0.00	0.00	0.12	0.01	1.17	0.29	0.00	0.00	5.50	0.02	12.76
49	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.03	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.00	0.04	0.00	0.03	0.03	0.01	0.00	0.00	0.22	1.85	0.51	0.87	0.00	0.01	0.05	0.00	0.72	0.09	0.00	0.00	4.06	0.01	8.70
50	0.09	0.03	0.00	0.01	0.02	0.03	0.00	0.03	0.12	0.68	0.03	0.00	0.00	0.00	0.02	0.01	0.00	0.03	0.02	0.02	0.03	0.00	0.05	0.00	0.04	0.04	0.02	0.00	0.00	1.60	0.89	0.24	5.43	0.00	0.00	0.24	0.02	37.54	0.50	0.00	0.00	2.98	0.73	51.50
51	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.01	0.01	0.01	0.00	0.02	0.00	0.09	0.03	0.06	0.01	0.00	0.32	3.34	0.63	2.62	0.00	0.00	0.12	0.01	1.22	0.21	0.00	0.00	4.45	0.02	13.31
52	0.33	0.44	0.07	0.14	0.18	0.09	0.15	0.02	0.24	0.06	0.16	0.00	0.00	0.00	0.43	0.26	0.02	1.00	0.95	0.14	0.19	0.01	0.31	0.00	0.30	0.11	0.19	0.02	0.02	0.44	5.75	1.20	12.72	0.00	0.06	0.32	0.02	3.01	0.48	0.00	0.00	58.67	0.02	88.57
53	0.07	0.21	0.02	0.07	0.12	0.08	0.02	0.01	0.06	0.05	0.16	0.00	0.00	0.00	0.29	0.05	0.01	0.17	1.57	0.08	0.06	0.00	0.09	0.00	0.06	0.04	0.06	0.01	0.00	0.16	2.94	0.78	2.74	0.00	0.01	0.25	0.01	2.79	0.12	0.00	0.00	24.44	0.02	37.61
54	0.31	0.33	0.27	0.27	0.38	0.24	0.05	0.02	0.71	0.09	0.49	0.00	0.00	0.00	0.94	0.25	0.01	0.49	1.08	0.23	0.04	0.00	0.12	0.00	0.17	0.18	0.13	0.01	0.00	0.63	5.52	0.86	7.36	0.00	1.86	0.70	0.02	3.51	2.07	0.00	0.00	30.35	0.04	59.76
55	0.04	0.11	0.01	0.02	0.04	0.02	0.01	0.07	0.06	0.08	0.03	0.00	0.00	0.00	0.09	0.03	0.00	0.11	0.16	0.08	0.14	0.02	0.14	0.00	0.20	0.60	0.12	0.01	0.00	5.49	5.42	1.38	5.40	0.00	0.01	1.06	0.03	1.92	0.36	0.00	0.00	18.63	0.03	41.92
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total																																												**564.86**

Rows=service subsystem branches (44. Wholesale and retail trade; repair of motor vehicles and motorcycles, 45. Hotels and restaurants, 46. Land transport; transport via pipelines, 47. Water and air transport, 48. Post and telecommunications, 49. Financial intermediation, 50. Real estate activities, 51. Renting of machinery and equipment , 52. Public administration and defense; compulsory social security, 53. Education, 54. Health and social work, 55. Sewage and refuse disposal, 56. Private households with employed persons).

Columns=Rest of the Economy (1. Rice growing, 2. Other cereals and crops, 3. Vegetables and horticultural growing, 4. Fruits growing , 5. Raw milk and milk products prepared in premises, 6. Cattle farming , 7. Other animal farming, 8. Forestry and logging , 9. Fishing, 10. Mining and quarrying, 11. Meat production , 12. Fish processing and fish products, 13. Fruit and vegetables processing and preserving, 14. Manufacture of vegetable and animal oils and fats, 15. Dairy products, 16. Rice mill products, 17. Flour and other grain mill , 18. Prepared animal feeds, 19. Bakery and similar farinaceous products, 20. Sugar and other food products, 21. Wines, 22. Manufacture of malt liquors and malt, 23. Distilling, rectifying and blending of spirits;, 24. Tobacco , 25. Spinning, weaving and finishing of textiles, 26. Knitted and crocheted fabrics and articles, 27. Dressing and dyeing of fur; manufacture of articles of fur, 28. Tanning and dressing and manufacture of leather, 29. Footwear, 30. Wood products , 31. Paper and paper products, 32. Publishing, printing and reproduction of recorded media, **33. Refined petroleum** , 34. Pesticides and other agro-chemical products , 35. Pharmaceuticals , 36. Basic chemicals , 37. Rubber and plastics products, **38. Other non-metallic mineral products**, 39. Basic metals , 40. Motor vehicles , 41. Furniture, **42. Electricity, gas and water supply**, 43. Building)

Note: cells are shaded according to the magnitude of the corresponding sectors in the total service subsystem CO_2 emissions spillover on the Rest of the Economy.

Figure 1: Uruguay GDP (US$: constant prices 2005)



Source: own elaboration based on Bonino et al. (2012).

Figure 2: Total services subsystem emissions decomposition

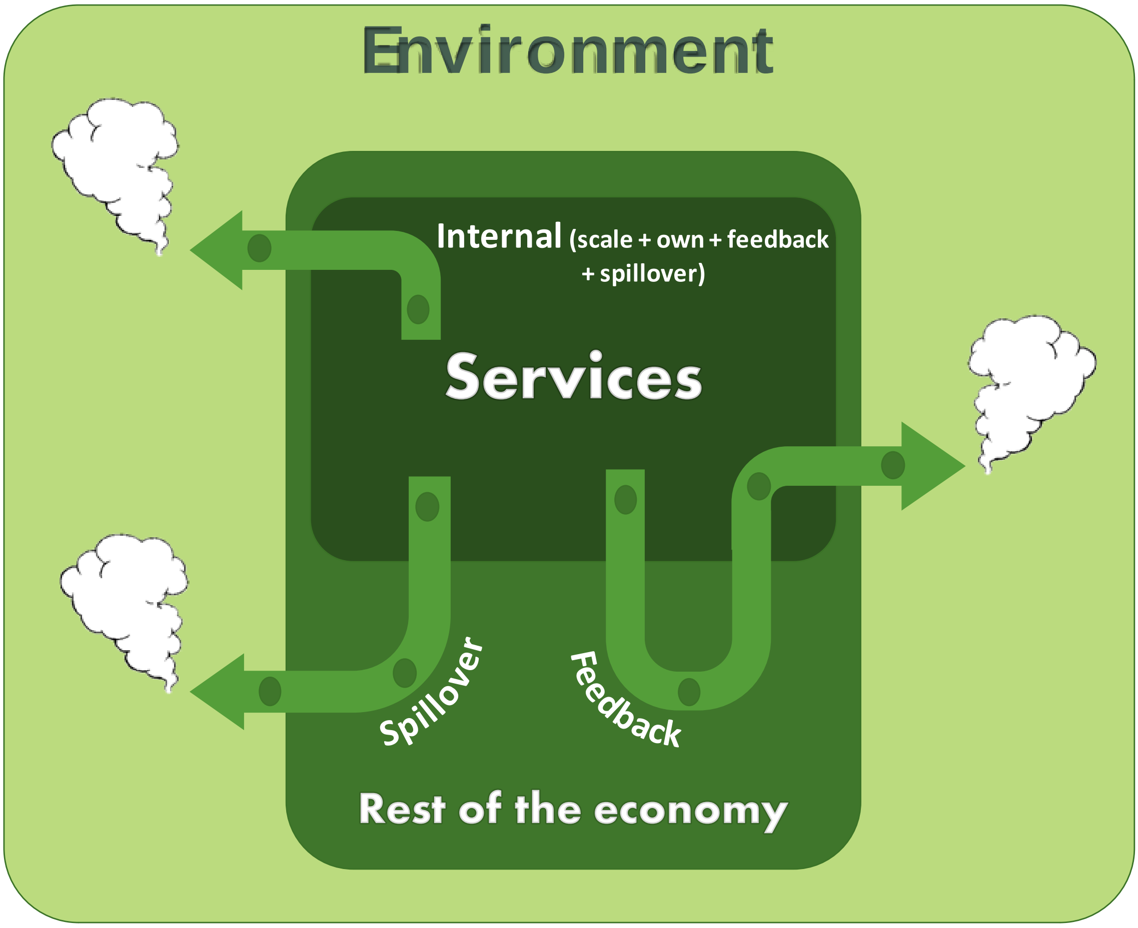


Table 1: Services subsystem sectors, output and direct and total CO_2 emissions

		Output		Direct CO_2		Total CO2					
Sector	**Name**	**US$:**	**%[a]**	**CO_2 Ktons**	**%[a]**	**Total CO_2 Ktons**	**%[a]**	**Exports CO_2 Ktons**	**%[a]**	**Domestic Cons. CO_2 Ktons**	**%[a]**
44	Wholesale and retail trade; repair of motor vehicles and motorcycles sectors	3,096.7	20.2%	14.8	0.5%	317.6	11.1%	35.2	3.5%	282.5	15.2%
45	Hotels and restaurants	867.3	5.7%	26.3	0.9%	161.9	5.7%	1.2	0.1%	160.6	8.6%
46	Land transport; transport via pipelines	957.5	6.2%	1261.2	45.3%	866.3	30.3%	196.5	19.6%	669.8	36.1%
47	Water and air transport	875.3	5.7%	1371.5	49.3%	962.9	33.6%	752.7	74.9%	210.2	11.3%
48	Post and telecommunications	777.8	5.1%	0.0	0.0%	35.4	1.2%	1.9	0.2%	33.4	1.8%
49	Financial intermediation	1,243.7	8.1%	1.5	0.1%	16.3	0.6%	7.6	0.8%	8.7	0.5%
50	Real estate activities	2,164.6	14.1%	0.0	0.0%	65.5	2.3%	0.2	0.0%	65.3	3.5%
51	Renting of machinery and equipment	941.1	6.1%	0.0	0.0%	22.6	0.8%	8.5	0.8%	14.2	0.8%
52	Public administration and defense; compulsory social security	1,238.2	8.1%	44.7	1.6%	159.2	5.6%	0.6	0.1%	158.6	8.5%
53	Education	722.0	4.7%	5.8	0.2%	51.5	1.8%	0.0	0.0%	51.5	2.8%
54	Health and social w ork	1,465.6	9.6%	16.9	0.6%	107.1	3.7%	0.0	0.0%	107.1	5.8%
55	Sew age and refuse disposal	795.0	5.2%	40.9	1.5%	96.0	3.4%	0.2	0.0%	95.8	5.2%
56	Private households w ith employed persons	192.3	1.3%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total services subsystem		**15,337**	**52,4%[b]**	**2783.7**	**45,7%[b]**	**2,862**	**46,9%[b]**	**1,005**	**35,1%[c]**	**1,858**	**64,9%[c]**
Total economy		**29,229**	**100%**	**6,097**	**100%**	**6,097**	**100%**	**2,397**	**39.3%**	**3,701**	**60.7%**

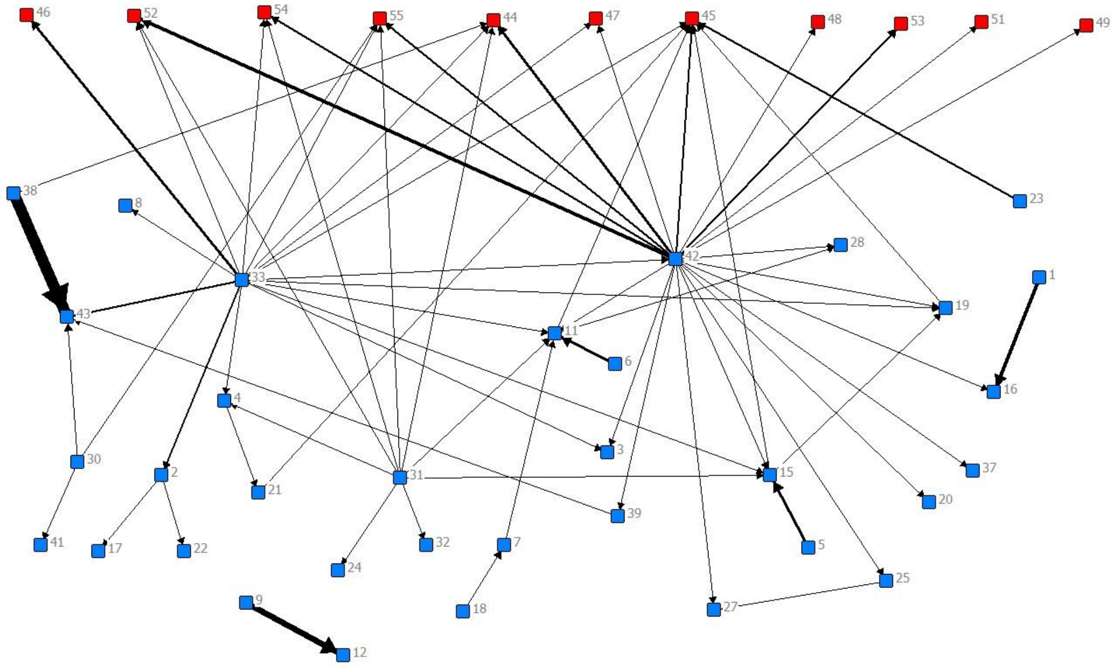
[a]branch % in total services subsystem
[b]Services subsystem share in reference to the total economy
[c]% of emissions consequence of exports and domestic consumption in reference to total emissions of the services subsystem
Source: ow n elaboration based in DNTEN (2008), Terra et al. (2009), and MVOTMA (2010a)

Table 2: Decomposition of the CO2 emissions of the services subsystem

Sector	Internal scale component	%	Internal own component	%	Internal feedback component	%	Internal spillover component	%	Feedback component	%	Spillover component	%	Total CO_2 Ktons	% Total CO_2 serv.
44	10.5	0.6%	0.5	0.7%	5.7	46.7%	194.0	58.2%	11.4	16.0%	95.5	16.9%	317.6	11.1%
45	23.9	1.3%	0.0	0.1%	1.2	9.9%	23.8	7.1%	17.1	23.9%	95.8	17.0%	161.9	5.7%
46	766.4	42.2%	44.5	69.1%	0.1	0.9%	7.2	2.2%	3.1	4.4%	45.0	8.0%	866.3	30.3%
47	921.9	50.8%	15.7	24.4%	0.4	3.7%	8.5	2.6%	1.9	2.7%	14.4	2.6%	962.9	33.6%
48	0.0	0.0%	0.0	0.0%	0.9	7.2%	20.2	6.0%	1.6	2.2%	12.8	2.3%	35.4	1.2%
49	0.6	0.0%	0.1	0.1%	0.3	2.4%	5.6	1.7%	1.0	1.4%	8.7	1.5%	16.3	0.6%
50	0.0	0.0%	0.0	0.0%	0.3	2.5%	5.9	1.8%	7.8	10.8%	51.5	9.1%	65.5	2.3%
51	0.0	0.0%	0.0	0.0%	0.3	2.8%	7.4	2.2%	1.6	2.3%	13.3	2.4%	22.6	0.8%
52	41.7	2.3%	0.0	0.0%	1.1	8.8%	21.8	6.5%	6.0	8.4%	88.6	15.7%	159.2	5.6%
53	5.7	0.3%	0.0	0.0%	0.2	1.9%	5.0	1.5%	2.9	4.0%	37.6	6.7%	51.5	1.8%
54	14.4	0.8%	2.1	3.3%	0.9	7.5%	18.6	5.6%	11.3	15.8%	59.8	10.6%	107.1	3.7%
55	30.7	1.7%	1.5	2.3%	0.7	5.7%	15.5	4.6%	5.8	8.1%	41.9	7.4%	96.0	3.4%
56	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%
Total services subsystem	**1,815.8**	**63.4%**	**64.4**	**2.2%**	**12.2**	**0.4%**	**333.5**	**11.7%**	**71.6**	**2.5%**	**564.9**	**19.7%**	**2,862**	**100%**
% of total CO_2 emissions	**29.8%**		**1.1%**		**0.2%**		**5.5%**		**1.2%**		**9.3%**		**46.9%**	

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

Figure 3: Most important linkages of the services subsystem spillover component and between the sectors of the rest of the economy



Note: This figure represents the linkages between the services subsystem and the rest of the economy and between sectors of the rest of the economy with a magnitude over 2 Ktons. This represents 68 graphs that account 87% of the whole emissions of this kind.

Figure 4: Services subsystem structural path analysis