Demand decomposition and subsystems input-output analysis of the CO_2 emissions of the service sector in the Philippines

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Abstract

The paper examines the role played by the service sector in the carbon dioxide emissions of the Philippines. It reconciles and distinguishes the emissions responsibility of the sector and the emissions embodied in the production of that sector. It also extends the subsystems input-output model applied to carbon dioxide emissions through demand decomposition. Input-output analysis of variables with adverse environmental consequences, like carbon dioxide, presents useful information on their links with the productive structure of the different sectors of the economy. Particularly, the subsystems model offers more details by decomposing emissions of a group of sectors into various components. This study proposes a further decomposition of the subsystems model by demand components so that the impact of domestic consumption and trade are also accounted for, recognizing the importance of trade in the economy and its corresponding trade policies. It utilizes the most recent 2006 Philippine input-output accounts and computes for sectoral carbon dioxide emissions from combustion of petroleum, coal and natural gas. It is found that over 65% emissions responsibility of service is due to the use of non-service input in meeting service demand. It is also shown from the study that the emissions responsibility of the service subsystem is almost 60% higher than that of the direct emissions or its embodied emissions in production, an insight that was made possible with the use of the subsystems framework. The Philippines despite being a net exporter of service turns out to be a net importer of embodied emissions, especially in the water transport sector. Additionally, the result of the proposed demand decomposition reveals that most of service's embodied emissions are from within-the-subsystem generated for meeting service demand. These results provide insights on the impact of the different demand components on emission generation of the service subsystem, among others, and may serve as aid for contemplating policies regarding the Philippine carbon dioxide mitigation program. Although the country only contributes around 0.3% of world emissions, marginal carbon dioxide reduction remains relevant for this economy identified as one of the most vulnerable to the detriments of climate change.

1. Introduction

Climate change remains one of the most pressing concerns of the current generation. Its manifestations include extreme weather conditions, rising water level and stronger natural disturbances. In 2013, the strongest hurricane in recorded modern history hit a region in the Philippines that resulted to immense devastation of lives and properties. Such occurrences that have adverse repercussions are not likely to vanish. Anthropogenic activities may have contributed to these changing weather patterns but human intervention can also be the key in mitigating such climate impact. For one, international accords have attempted to make economies commit to carbon dioxide emissions reduction. Many economies have responded by adopting policies for regulating carbon dioxide emissions directly and indirectly.

In the Philippines, power or electricity generation has been identified as the key sector in carbon dioxide emission (Reyes, 2009). This result is expected considering the intensive use of this sector of the more polluting fossil fuels, the currently cheapest fuel for power generation. Policy makers are not unaware of this fact. There are initiatives and concrete steps being taken by the energy sector to phase in more use of cleaner renewable energy resources and promoting energy efficiency.

Putting aside the obvious, little attention is paid to the contribution of the service sector on carbon dioxide emissions. This sector may seem to be a relatively clean sector in terms of emissions, unlike the industry or the manufacturing sectors, in the absence of any further investigation. There is in fact no literature at all in the Philippines that looks closely at the emissions generation mechanism of this sector and the regulations governing the sector may be scant except for the transportation services. Thus, this study aims to inform and contribute to the understanding of the effect of the service sector on the country's carbon dioxide emissions. The results of this paper are intended for shedding light on the issue and enabling the policy makers to arrive at a set of well-crafted and correctly targeted policies on an often neglected segment of the economy in terms of its role on emissions generation.

The service sector is especially interesting in the Philippines because of its increasing share in the country's output. As a proportion of gross domestic product, its share was at 57.7% and has risen by 7.1% in 2013 alone. The contributions of the agriculture and the industry sectors pale in comparison at 11.2% and 31%, respectively (Philippine Statistics Authority, 2014). Such a large share in the economy warrants a thorough inspection of the emissions responsibility of the service sector.

A similar focus on the emissions of the service sector is reflected in the studies of Alcantara and Padilla (2009) and Butnar and Llop (2011) for Spain. Both use input-output subsystems approach. The input-output framework has become one of the most valuable tools for analyzing environmental effects of a production system. From its inception, Leontief himself extended it for assessing environmental repercussions (1970). The environmental input-output model has since been used in studying pollution, energy, and water usage, among others. Some notable applications on carbon dioxide emissions include those of Lenzen (1998), Machado et al. (2001), Munksgaard and Pedersen (2001), Reinert and Roland-Holst (2001), Lenzen et al. (2004), Sanchez Choliz and Duarte (2004), Peters and Hertwich (2006, 2008), Wiedmann et al. (2007), and Chen and Zhang (2010).

The subsystems model, in particular, allows studying the interrelationships of a specific sector or group of sectors, referred to as a subsystem, keeping it part of the whole production system, yet providing more refined information about its production relations. The first reference to subsystems is by Sraffa (1960) as an appendix to his book. In his words, "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. The parts we shall call 'sub-systems'"(p. 89).

Subsequently, the theory is further developed from the contributions of Pasinetti (1973, 1988), Deprez (1990), Scazzieri (1990), among others. Alcantara and Padilla (2009) apply the analysis to the carbon dioxide emissions of the service subsystem in Spain while Butnar and Llop (2011) extend the study with structural decomposition. Later, Llop and Tol (2013) treat each sector in the Irish economy as a subsystem for decomposing sectoral greenhouse gas emissions.

This paper extends the subsystems input-output analysis by decomposing the service sector's emissions to demand components to isolate the trade effects and to distinguish the emissions embodied in production from the emissions embodied in domestic consumption. This highlights the role of trade in transferring emissions responsibility to the final consumers of the goods. Further, the embodied emissions are classified to either within-the-subsystem generated or from-outside-the-subsystem. Such analysis gives a better picture of service's emission generation and provides background information to stakeholders and policy makers for conceiving emissions mitigation policies and interventions.

The rest of the paper is organized as follows. Section 2 discusses the framework for the subsystems input-output model and clarifies the reconciliation between emissions responsibility and direct emissions of the subsystem. Section 3 details the proposed demand decomposition. The results are presented in Section 4, and Section 5 concludes and gives preliminary insights.

2. Input-Output Subsystems Model

Input-output analysis of variables with adverse environmental consequences, like carbon dioxide, presents useful information on their links with the productive structure of the different sectors of the economy. Particularly, the subsystems model allows isolating the impacts of a group of sectors and offers more details by decomposing the impact into various components.

Consistent with the literature, the input-output system is decomposed into two subsystems: M, with 1, 2, ..., m non-service sectors, and S, with m+1, ..., n service sectors. Thus, the matrices in the input-output model are partitioned as follows

$$\begin{pmatrix} \mathbf{A}_{\mathrm{MM}} & \mathbf{A}_{\mathrm{MS}} \\ \mathbf{A}_{\mathrm{SM}} & \mathbf{A}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix}. \tag{1}$$

In the above, $\mathbf{A}$ is the matrix of direct requirements coefficients or the technical coefficients matrix, $\boldsymbol{x}$ is the vector of output and $\boldsymbol{y}$ is the vector of final demand. The subscripts and superscripts have their obvious interpretations.

The solution is given by

$$\begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix}, \tag{2}$$

where the Leontief inverse **B** is defined as

$$\begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} = \left[\begin{pmatrix} \mathbf{I} & 0 \\ 0 & \mathbf{I} \end{pmatrix} - \begin{pmatrix} \mathbf{A}_{\mathrm{MM}} & \mathbf{A}_{\mathrm{MS}} \\ \mathbf{A}_{\mathrm{SM}} & \mathbf{A}_{\mathrm{SS}} \end{pmatrix} \right]^{-1}, \tag{3}$$

and **I** is the identity matrix.

Substituting equation (2) to equation (1) gives the basic model of subsystems input-output analysis as follows

$$\begin{pmatrix} \mathbf{A}_{\mathrm{MM}} & \mathbf{A}_{\mathrm{MS}} \\ \mathbf{A}_{\mathrm{SM}} & \mathbf{A}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix}. \tag{4}$$

Further decomposition of matrix **A** to $\mathbf{A}^{\mathrm{D}}$ and $\mathbf{A}^{0}$, similar to Alcantara and Padilla (2009), yields

$$\left[\begin{pmatrix} \mathbf{A}^{\mathrm{D}}_{\mathrm{MM}} & 0 \\ 0 & \mathbf{A}^{\mathrm{D}}_{\mathrm{SS}} \end{pmatrix} + \begin{pmatrix} \mathbf{A}^{0}_{\mathrm{MM}} & \mathbf{A}^{0}_{\mathrm{MS}} \\ \mathbf{A}^{0}_{\mathrm{SM}} & \mathbf{A}^{0}_{\mathrm{SS}} \end{pmatrix} \right] \begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix}. \tag{5}$$

Matrix $\mathbf{A}^{\mathrm{D}}$ comprises of the diagonal elements of **A** and zero elsewhere while matrix $\mathbf{A}^{0}$ has the elements of **A** but with the principal diagonal composed of zeros.

Premultiplying equation (5) with the diagonalized direct emissions intensities, or the carbon dioxide emissions generated per unit of output by the different sectors, allows segregating the emissions associated with production to various components as presented below

$$\begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \left\{ \left[\begin{pmatrix} \mathbf{A}^{\mathrm{D}}_{\mathrm{MM}} & 0 \\ 0 & \mathbf{A}^{\mathrm{D}}_{\mathrm{SS}} \end{pmatrix} + \begin{pmatrix} \mathbf{A}^{0}_{\mathrm{MM}} & \mathbf{A}^{0}_{\mathrm{MS}} \\ \mathbf{A}^{0}_{\mathrm{SM}} & \mathbf{A}^{0}_{\mathrm{SS}} \end{pmatrix} \right] \begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} \right\} = \begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix}. \tag{6}$$

To describe the emissions that the service subsystem is responsible for, we need to account not only for the direct emissions of the sectors but the emissions that are generated to meet the intermediate demand for service, the final demand for service, and the intermediate demand for non-service to meet the final demand of service. To account for these, $\boldsymbol{y}^{\mathrm{M}}$ is set to zero and the matrix image of equation (6) is then presented as

$$\begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \left\{ \left[\begin{pmatrix} \mathbf{A}^{\mathrm{D}}_{\mathrm{MM}} & 0 \\ 0 & \mathbf{A}^{\mathrm{D}}_{\mathrm{SS}} \end{pmatrix} + \begin{pmatrix} \mathbf{A}^{0}_{\mathrm{MM}} & \mathbf{A}^{0}_{\mathrm{MS}} \\ \mathbf{A}^{0}_{\mathrm{SM}} & \mathbf{A}^{0}_{\mathrm{SS}} \end{pmatrix} \right] \begin{pmatrix} \mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} \\ \mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} 0 \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} \right\} = \begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}}_{\mathrm{S}} \\ \boldsymbol{x}^{\mathrm{S}}_{\mathrm{S}} \end{pmatrix}, \tag{7}$$

where $\boldsymbol{x}^{\mathrm{M}}_{\mathrm{S}}$ is the production of non-service to meet the service final demand and $\boldsymbol{x}^{\mathrm{S}}_{\mathrm{S}}$ is the production of service to meet service demand.

Equation (7) can be alternatively expressed as

$$\widehat{\mathbf{c}_{\mathrm{M}}}\left(\mathbf{A}^{\mathrm{D}}_{\mathrm{MM}}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}^{0}_{\mathrm{MM}}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}^{0}_{\mathrm{MS}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}\right) = \widehat{\mathbf{c}_{\mathrm{M}}}\boldsymbol{x}^{\mathrm{M}}_{\mathrm{S}}, \tag{8}$$

$$\widehat{\boldsymbol{c}}_{\mathrm{S}}\left(\mathbf{A}_{\mathrm{SS}}^{\mathrm{D}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}_{\mathrm{SM}}^{0}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}_{\mathrm{SS}}^{0}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}} + \boldsymbol{y}^{\mathrm{S}}\right) = \widehat{\boldsymbol{c}}_{\mathrm{S}}\boldsymbol{x}_{\mathrm{S}}^{\mathrm{S}}. \tag{9}$$

The components of the emissions of the service subsystem come from equations (8) and (9). The emissions computed from equation (8) refer to the external component of the service sectors, $\mathbf{EC}_{\mathrm{S}}$, or the emissions arising from the production of the non-service sectors to meet the demand of the service sectors.[1] The own component, $\mathbf{OC}_{\mathrm{S}}$, feedback component, $\mathbf{FC}_{\mathrm{S}}$, internal component, $\mathbf{INT}_{\mathrm{S}}$, and demand level component, $\mathbf{DLC}_{\mathbf{S}}$, of the service subsystem emissions are subsequently captured by the four terms on the left hand side of equation (9), respectively.[2] These are all presented below as

$$\mathbf{EC}_{\mathrm{S}} = \widehat{\boldsymbol{c}}_{\mathrm{M}}\left(\mathbf{A}_{\mathrm{MM}}^{\mathrm{D}}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}_{\mathrm{MM}}^{0}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \mathbf{A}_{\mathrm{MS}}^{0}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}\right) = \widehat{\boldsymbol{c}}_{\mathrm{M}}\mathbf{A}_{\mathrm{MM}}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}} + \widehat{\boldsymbol{c}}_{\mathrm{M}}\mathbf{A}_{\mathrm{MS}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}, \tag{10}$$

$$\mathbf{OC}_{\mathrm{S}} = \widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SS}}^{\mathrm{D}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}, \tag{11}$$

$$\mathbf{FC}_{\mathrm{S}} = \widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SM}}^{0}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}}, \tag{12}$$

$$\mathbf{INT}_{\mathrm{S}} = \widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SS}}^{0}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}, \tag{13}$$

$$\mathbf{DLC}_{\mathrm{S}} = \widehat{\boldsymbol{c}}_{\mathrm{S}}\boldsymbol{y}^{\mathrm{S}}. \tag{14}$$

The emissions from service's own component pertain to those arising from the production of the service sector that goes to the same service sector in the subsystem as an intermediate input to satisfy the service subsystem's final demand. The feedback component measures the emissions of service in producing non-service intermediate product that is fed back to the service subsystem for meeting its final demand. The emissions from the internal component, on the other hand, come from the intermediate use of a service sector of the rest of the other service sectors' output to supply the service subsystem's final demand. Finally, the demand level component measures the emissions generated by the service subsystem to meet its final demand. $\mathbf{OC}_{\mathrm{S}}$, $\mathbf{FC}_{\mathrm{S}}$ and $\mathbf{INT}_{\mathrm{S}}$ refer then to the subsystems' emissions associated with meeting the intermediate input demand while the $\mathbf{DLC}_{\mathbf{S}}$ captures those from final demand.

Hence, the emissions responsibility of the service subsystem, $\mathbf{E}_{\mathrm{S}}$, can be computed as

$$\mathbf{E}_{\mathrm{S}} = \mathbf{OC}_{\mathrm{S}} + \mathbf{FC}_{\mathrm{S}} + \mathbf{INT}_{\mathrm{S}} + \mathbf{DLC}_{\mathrm{S}} + \mathbf{EC}_{\mathrm{S}}. \tag{15}$$

These emissions do not sum up to the actual emissions of the service sector. These are overstated by the external component, comprising of non-service emissions, and understated by the emissions of the service sectors to satisfy demand of the non-service sectors. The latter can be calculated from equation (6) when $\boldsymbol{y}^{\mathrm{S}} = 0$ such as

$$\begin{pmatrix} \widehat{\boldsymbol{c}}_{\mathrm{M}} & 0 \\ 0 & \widehat{\boldsymbol{c}}_{\mathrm{S}} \end{pmatrix} \left\{ \left[\begin{pmatrix} \mathbf{A}_{\mathrm{MM}}^{\mathrm{D}} & 0 \\ 0 & \mathbf{A}_{\mathrm{SS}}^{\mathrm{D}} \end{pmatrix} + \begin{pmatrix} \mathbf{A}_{\mathrm{MM}}^{0} & \mathbf{A}_{\mathrm{MS}}^{0} \\ \mathbf{A}_{\mathrm{SM}}^{0} & \mathbf{A}_{\mathrm{SS}}^{0} \end{pmatrix} \right] \begin{pmatrix} \mathbf{B}_{\mathrm{MM}}\boldsymbol{y}^{\mathrm{M}} \\ \mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ 0 \end{pmatrix} \right\} = \begin{pmatrix} \widehat{\boldsymbol{c}}_{\mathrm{M}} & 0 \\ 0 & \widehat{\boldsymbol{c}}_{\mathrm{S}} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}_{\mathrm{M}}^{\mathrm{M}} \\ \boldsymbol{x}_{\mathrm{M}}^{\mathrm{S}} \end{pmatrix}, \tag{16}$$

[1] Alcantara and Padilla (2009) refer to this as the spillover component.

[2] The own component, feedback component and internal component are not disaggregated by Butnar & Llop (2011) and Llop and Tol (2013) but instead reported altogether as the internal component.

where $\boldsymbol{x}_{\mathrm{M}}^{\mathrm{M}}$ is the production of non-service to meet non-service demand and $\boldsymbol{x}_{\mathrm{M}}^{\mathrm{S}}$ is the production of service to meet non-service demand, and when $\boldsymbol{x}_{\mathrm{M}}^{\mathrm{M}}=0$ as follows

$$\begin{pmatrix}\widehat{\mathbf{c}_{\mathrm{M}}} & 0\\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}}\end{pmatrix}\left[\begin{pmatrix}\mathbf{A}_{\mathrm{MM}} & \mathbf{A}_{\mathrm{MS}}\\ \mathbf{A}_{\mathrm{SM}} & \mathbf{A}_{\mathrm{SS}}\end{pmatrix}\begin{pmatrix}\mathbf{B}_{\mathrm{MM}}\boldsymbol{y}^{\mathrm{M}}\\ \mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}}\end{pmatrix}+\begin{pmatrix}\boldsymbol{y}^{\mathrm{M}}\\ 0\end{pmatrix}\right]=\begin{pmatrix}\widehat{\mathbf{c}_{\mathrm{M}}} & 0\\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}}\end{pmatrix}\begin{pmatrix}0\\ \boldsymbol{x}_{\mathrm{M}}^{\mathrm{S}}\end{pmatrix}. \tag{17}$$

Alternatively, the above can be expressed as

$$\widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SM}}\mathbf{B}_{\mathrm{MM}}\boldsymbol{y}^{\mathrm{M}}+\widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SS}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}}=\widehat{\boldsymbol{c}}_{\mathrm{S}}\boldsymbol{x}_{\mathrm{M}}^{\mathrm{S}}. \tag{18}$$

Equation (17) measures the induced component, $\mathbf{IND}_{\mathrm{S}}$, or the service sector emissions induced by the demand from the non-service sectors.[3] Thus,

$$\mathbf{IND}_{\mathrm{S}}=\widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SM}}\mathbf{B}_{\mathrm{MM}}\boldsymbol{y}^{\mathrm{M}}+\widehat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{A}_{\mathrm{SS}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}}. \tag{19}$$

This study contributes to the literature on subsystems input-output modelling by explicitly reconciling the emissions responsibility of the sector, $\mathbf{E}_{\mathrm{S}}$, with the emissions embodied in the production of that sector, $\mathbf{EEP}^{\mathrm{S}}$, i.e., the total emissions of the service sector. It can be shown that the latter can be computed as

$$\mathbf{EEP}^{\mathrm{S}}=\mathbf{OC}_{\mathrm{S}}+\mathbf{FC}_{\mathrm{S}}+\mathbf{INT}_{\mathrm{S}}+\mathbf{DLC}_{\mathrm{S}}+\mathbf{IND}_{\mathrm{S}}. \tag{20}$$

This can be mapped to the emissions responsibility of the service subsystem as follows

$$\mathbf{EEP}^{\mathrm{S}}=\mathbf{ES}_{\mathrm{S}}-\mathbf{EC}_{\mathrm{S}}+\mathbf{IND}_{\mathrm{S}}. \tag{21}$$

Note that it can also be shown that the external component of one subsystem is also the induced component of the other subsystem so that $\mathbf{EC}_{\mathrm{S}}=\mathbf{IND}_{\mathrm{M}}$ and $\mathbf{IND}_{\mathrm{S}}=\mathbf{EC}_{\mathrm{M}}$. Say the M subsystem is the subsystem of interest, $\mathbf{IND}_{\mathrm{M}}$ is computed when $\boldsymbol{y}^{\mathrm{M}}$ is set to zero as in equation (7) and $\boldsymbol{x}_{\mathrm{S}}^{\mathrm{S}}=0$ so that $\mathbf{IND}_{\mathrm{M}}=\mathbf{c}_{\mathrm{M}}\mathbf{A}_{\mathrm{MM}}\mathbf{B}_{\mathrm{MS}}\boldsymbol{y}^{\mathrm{S}}+\mathbf{c}_{\mathrm{M}}\mathbf{A}_{\mathrm{MS}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}$. On the other hand, $\mathbf{EC}_{\mathrm{M}}$ is calculated when $\boldsymbol{y}^{\mathrm{S}}=0$ and $\boldsymbol{x}_{\mathrm{M}}^{\mathrm{M}}=0$ as in equation (17) such that $\mathbf{EC}_{\mathrm{M}}=\mathbf{c}_{\mathrm{S}}\mathbf{A}_{\mathrm{SM}}\mathbf{B}_{\mathrm{MM}}\boldsymbol{y}^{\mathrm{M}}+\mathbf{c}_{\mathrm{S}}\mathbf{A}_{\mathrm{SS}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}}$.

3. Demand Decomposition

Having described the mapping of the decomposed emissions of the service sectors, this study proposes a further decomposition of the subsystems model by demand components to account for the impact of domestic consumption and trade, recognizing the importance of trade in the economy and its corresponding trade policies. This decomposition allows distinguishing the emissions embodied in production from the emissions embodied in consumption. At the same time, it also permits differentiating the within-the-subsystem embodied emissions and outside-the-subsystem embodied emissions.

We begin by showing the emissions balance equation as

[3] The label induced component is introduced by Llop and Tol (2013) but not mapped in the same manner as in this paper.

$$\mathbf{c}\boldsymbol{x} = \mathbf{c}(\mathbf{I} - \mathbf{A})^{-1}\boldsymbol{y}, \tag{22}$$

where $\mathbf{c}$ still represents the carbon dioxide emissions generated per unit of output. When $\mathbf{c}$ is multiplied with the output vector, $\boldsymbol{x}$, the total emissions in producing $\boldsymbol{x}$ is computed. On the right hand side, multiplying $\mathbf{c}$ with the Leontief inverse traces the carbon dioxide emissions associated with the direct and indirect production requirements needed for meeting a unit of final demand. Multiplying this with the vector of final demand, $\boldsymbol{y}$, computes for the total emissions that must balance with the left hand side.

Then, equation (22) can be expressed in terms of the subsystems model formulation so that premultiplying the solution of the input-output model in equation (2) by the diagonalized direct emissions intensities yields the total direct emissions as follows

$$\begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \begin{pmatrix} \boldsymbol{x}^{\mathrm{M}} \\ \boldsymbol{x}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}} & 0 \\ 0 & \widehat{\mathbf{c}_{\mathrm{S}}} \end{pmatrix} \begin{pmatrix} \mathbf{B}_{\mathrm{MM}} & \mathbf{B}_{\mathrm{MS}} \\ \mathbf{B}_{\mathrm{SM}} & \mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix}. \tag{23}$$

The product of the first two matrices on the right hand side of equation (23) refers to the embodied emissions intensity such that the embodied emissions in production can be computed as the product of the embodied emission intensity matrix and the final demand vector. Therefore,

$$\mathbf{EEP} = \begin{pmatrix} \widehat{\mathbf{c}_{\mathrm{M}}}\mathbf{B}_{\mathrm{MM}} & \widehat{\mathbf{c}_{\mathrm{M}}}\mathbf{B}_{\mathrm{MS}} \\ \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SM}} & \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix}. \tag{24}$$

Focusing on the service sectors requires defining $\widehat{\mathbf{c}_{\mathrm{M}}}$ as null to isolate the embodied emissions in the production of service like below

$$\mathbf{EEP}^{\mathrm{S}} = \begin{pmatrix} 0 & 0 \\ \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SM}} & \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix}. \tag{25}$$

Alternatively,

$$\mathbf{EEP}^{\mathrm{S}} = \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{y}^{\mathrm{M}} + \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{y}^{\mathrm{S}}. \tag{26}$$

Now, to perform the demand decomposition, the final demand is segregated into three components as follows

$$\begin{pmatrix} \boldsymbol{y}^{\mathrm{M}} \\ \boldsymbol{y}^{\mathrm{S}} \end{pmatrix} = \begin{pmatrix} \boldsymbol{D}^{\mathrm{M}} \\ \boldsymbol{D}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{EX}^{\mathrm{M}} \\ \boldsymbol{EX}^{\mathrm{S}} \end{pmatrix} - \begin{pmatrix} \boldsymbol{IM}^{\mathrm{M}} \\ \boldsymbol{IM}^{\mathrm{S}} \end{pmatrix}, \tag{27}$$

where $\boldsymbol{D}$ is the vector of domestic demand or the consumption of the domestic economy, $\boldsymbol{EX}$ refers to the vector of exports, and $\boldsymbol{IM}$ refers to the imports vector. Note that the $\boldsymbol{y}$ vector refers to the final demand for domestically produced output or the production of the domestic economy.

The embodied emission in production of the service sectors in equation (25) can also then be written as

$$\mathbf{EEP}^{\mathrm{S}} = \begin{pmatrix} 0 & 0 \\ \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SM}} & \widehat{\mathbf{c}_{\mathrm{S}}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \left[\begin{pmatrix} \boldsymbol{D}^{\mathrm{M}} \\ \boldsymbol{D}^{\mathrm{S}} \end{pmatrix} + \begin{pmatrix} \boldsymbol{EX}^{\mathrm{M}} \\ \boldsymbol{EX}^{\mathrm{S}} \end{pmatrix} - \begin{pmatrix} \boldsymbol{IM}^{\mathrm{M}} \\ \boldsymbol{IM}^{\mathrm{S}} \end{pmatrix} \right]. \tag{28}$$

The embodied emissions in exports, $\mathbf{EEE}^{\mathrm{S}}$, is the product of the embodied emissions intensity matrix and the exports vector. Similarly, the embodied emissions in imports, $\mathbf{EEI}^{\mathrm{S}}$, comprises of the embodied emissions intensity matrix multiplied by the imports vector. Hence,

$$\mathbf{EEE}^{\mathrm{S}} = \begin{pmatrix} 0 & 0 \\ \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}} & \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{EX}^{\mathrm{M}} \\ \boldsymbol{EX}^{\mathrm{S}} \end{pmatrix} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{EX}^{\mathrm{M}} + \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{EX}^{\mathrm{S}}, \tag{29}$$

$$\mathbf{EEI}^{\mathrm{S}} = \begin{pmatrix} 0 & 0 \\ \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}} & \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{IM}^{\mathrm{M}} \\ \boldsymbol{IM}^{\mathrm{S}} \end{pmatrix} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{IM}^{\mathrm{M}} + \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{IM}^{\mathrm{S}}. \tag{30}$$

From equation (29), the exported emissions of service can be decomposed into two components, the non-service embodied emissions of exports, $\mathbf{EEE}_{\mathrm{M}}^{\mathrm{S}}$, and the service embodied emissions of exports, $\mathbf{EEE}_{\mathrm{S}}^{\mathrm{S}}$. Specifically,

$$\mathbf{EEE}_{\mathrm{M}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{EX}^{\mathrm{M}}, \tag{31}$$

$$\mathbf{EEE}_{\mathrm{S}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{EX}^{\mathrm{S}}. \tag{32}$$

Similarly, from equation (30), the imported emissions of service can be decomposed into two components, the non-service embodied emissions of imports, $\mathbf{EEI}_{\mathrm{M}}^{\mathrm{S}}$, and the service embodied emissions of imports, $\mathbf{EEI}_{\mathrm{S}}^{\mathrm{S}}$. Thus,

$$\mathbf{EEI}_{\mathrm{M}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{IM}^{\mathrm{M}}, \tag{33}$$

$$\mathbf{EEI}_{\mathrm{S}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{IM}^{\mathrm{S}}. \tag{34}$$

The difference of equations (29) and (30) gives the embodied emissions in international trade balance, $\mathbf{EEB}^{\mathrm{S}}$, as

$$\mathbf{EEB}^{\mathrm{S}} = \mathbf{EEE}^{\mathrm{S}} - \mathbf{EEI}^{\mathrm{S}}. \tag{35}$$

This as well can be decomposed to two parts, the non-service embodied emissions of trade balance and the service embodied emissions of trade balance as follows

$$\mathbf{EEB}_{\mathrm{M}}^{\mathrm{S}} = \mathbf{EEE}_{\mathrm{M}}^{\mathrm{S}} - \mathbf{EEI}_{\mathrm{M}}^{\mathrm{S}}, \tag{36}$$

$$\mathbf{EEB}_{\mathrm{S}}^{\mathrm{S}} = \mathbf{EEE}_{\mathrm{S}}^{\mathrm{S}} - \mathbf{EEI}_{\mathrm{S}}^{\mathrm{S}}. \tag{37}$$

Like in equations (29) and (30), the embodied emissions in consumption of the domestic economy, $\mathbf{EEC}^{\mathrm{S}}$, can be calculated as the product of the embodied emissions intensity matrix and the domestic demand vector such as

$$\mathbf{EEC}^{\mathrm{S}} = \begin{pmatrix} 0 & 0 \\ \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}} & \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}} \end{pmatrix} \begin{pmatrix} \boldsymbol{D}^{\mathrm{M}} \\ \boldsymbol{D}^{\mathrm{S}} \end{pmatrix} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{D}^{\mathrm{M}} + \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{D}^{\mathrm{S}}, \tag{38}$$

or it can be derived merely as the difference between the embodied emissions in production and the embodied emissions in international trade like below

$$\mathbf{EEC}^{\mathrm{S}} = \mathbf{EEP}^{\mathrm{S}} - \mathbf{EEE}^{\mathrm{S}} + \mathbf{EEI}^{\mathrm{S}} = \mathbf{EEP}^{\mathrm{S}} - \mathbf{EEB}^{\mathrm{S}}. \tag{39}$$

Finally, the service subsystem's embodied emission in consumption can be decomposed to the non-service embodied emissions of consumption and the service embodied emissions of consumption. Therefore,

$$\mathbf{EEC}_{\mathrm{M}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SM}}\boldsymbol{D}^{\mathrm{M}}, \tag{40}$$

$$\mathbf{EEC}_{\mathrm{S}}^{\mathrm{S}} = \hat{\boldsymbol{c}}_{\mathrm{S}}\mathbf{B}_{\mathrm{SS}}\boldsymbol{D}^{\mathrm{S}}, \tag{41}$$

and in terms of differences,

$$\mathbf{EEC}_{\mathrm{M}}^{\mathrm{S}} = \mathbf{EEP}_{\mathrm{M}}^{\mathrm{S}} - \mathbf{EEB}_{\mathrm{M}}^{\mathrm{S}}, \tag{42}$$

$$\mathbf{EEC}_{\mathrm{S}}^{\mathrm{S}} = \mathbf{EEP}_{\mathrm{S}}^{\mathrm{S}} - \mathbf{EEB}_{\mathrm{S}}^{\mathrm{S}}. \tag{43}$$

Note that for other applications, the service embodied emissions and non-service embodied emissions can be generalized to within-the-subsystem embodied emissions and outside-the-subsystem embodied emissions.

This demand side decomposition of the service subsystem's emissions provides more details and adds dimension to the analysis and understanding of emissions. The trade dimension is incorporated which is inevitably present in modern economies. The model described in this study is a single region model. The trade dimension is ideally treated using an MRIO approach when the data permits.[4] There should be no deviation on the emissions embodied in exports but the emissions embodied in imports provide a good approximation using this approach.

4. Empirical Application to the Philippine Service Sectors

For the empirical application, the latest official Philippine input-output table (National Statistical Coordination Board, 2014) is used, that of year 2006. The industrial carbon dioxide emissions from the combustion of petroleum, coal and natural gas for the same year are calculated for each sector, as in Reyes (2009).[5] The sectoral classification of the fuel data reported by the Department of Energy drove the sectoral aggregation of the original 70 input-output sectors to 26 sectors. Of the 26 sectors, 20 are non-service and six are service sectors. The service subsystem contributes 15% of the total production emissions but is responsible for more than double that at 35%.

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[4] See Lenzen et al. (2004) and Peters and Hertwich (2008) for details on multi-region input-output model applications to carbon dioxide.

[5] CO_2 from petroleum is the summation of petroleum demand per fuel type in barrels x (fuel density in grams/gal x 3,780 x 200 x C ratio x 44/12 molar mass ratio). CO_2 from coal except for power generation is computed as coal consumption in MT x 1,000 X 60% C ratio x 44/12 molar mass ratio. CO_2 from coal for power generation is calculated as power generated from coal in GWh x 3.6 x 100,000 x 60% C ratio x 44/12 molar mass ratio. CO_2 from natural gas is equal to the natural gas consumption in MMSCF x 55,623.33 kg CO_2 per MMSCF of natural gas, based on kg of CO_2 per MMSCF of natural gas computed as 20.5 natural gas density in grams/SCF/1,000 x 1,000,000 x 74% C ratio x 44/12 molar mass ratio.

The result of the decomposition analysis is presented in Table 1. Among the sectors of the service subsystem, wholesale and retail trade is found to have the largest own component emissions at 226.11 kt. Land transport follows in magnitude at only 31.94 kt. The own component, or the emissions arising from own use of each sector in the service subsystem as input in production, happens to be relatively small consisting of 1.9% of the total emissions responsibility of the service subsystem. The feedback component of service, on the other hand, is the smallest contributing only 1.1% of the emissions responsibility, with the wholesale and retail trade again appearing to be especially large at 109.72 kt. This means that the wholesale and retail trade sector, among all the other service sectors, has the biggest emissions from feeding its output to non-service sectors that are used to produce back service.

As for internal component that constitutes 3.0% of service subsystem's emissions responsibility, most of it turns out to be from the air transport sector at 190.24 kt of carbon dioxide. This implies that a large percentage of air transport's emissions are from supplying input to other service sectors. The second largest magnitude of internal component emissions is from the land transport sector at 124.24 kt of carbon dioxide. When the own, feedback and internal components are all added up for every service sector, wholesale and retail trade is still found to have the most significant role in emitting carbon dioxide for meeting intermediate demand for service.

Table 1. Decomposition of the CO2 emissions responsibility of the service subsystem (kt)

Service Sectors	Own Component	Feedback Component	Internal Component	Demand Level Component	External Component	Total Emissions Responsibility	%
	OC_S	**FC_S**	**INT_S**	**DLC_S**	**EC_S**	**E_S**	
Land transport	31.94	31.47	124.24	1,180.68	1,384.32	**2,752.65**	*18.4*
Water transport	3.88	14.61	60.43	1,674.05	267.32	**2,020.29**	*13.5*
Air transport	11.49	4.33	190.24	495.19	494.89	**1,196.15**	*8.0*
Wholesale and retail trade	226.11	109.72	64.75	794.67	150.51	**1,345.76**	*9.0*
Finance and housing	1.66	0.15	1.39	6.83	2,307.50	**2,317.53**	*15.5*
Private and public services	7.93	0.92	4.16	64.91	5,227.82	**5,305.74**	*35.5*
Total	283.01	161.22	445.20	4,216.32	9,832.35	**14,938.11**	*100.0*
%	*1.9*	*1.1*	*3.0*	*28.2*	*65.8*	*100.0*	

Still from Table 1, two of the transportation sectors are shown to have the highest demand level component of emissions with water transport posting 1,674 kt of emissions while land transport emitting 1,181 kt of carbon dioxide. The most significant component of the service subsystem's emissions responsibility is the external component, i.e., 65.8% are emissions arising from the production of the non-service sectors to meet the demand of the service sectors. Notably, private and public services sector accounts for 5,228 kt of carbon dioxide, more than half of total external component emissions. Moreover, of the service subsystem, more than a third of the emissions responsibility falls on private and public services. Finance and housing sector and land transport sector also have considerable external component emissions at 2,308 kt and 1,384 kt, respectively. This makes land transport a runner up in terms of emissions responsibility, while finance and housing turns out to have the third largest contribution.

Table 2. Mapping of the CO2 components to the actual emissions of the service subsystem (kt)

Service Sectors	Own Component **OC_S**	Feedback Component **FC_S**	Internal Component **INT_S**	Demand Level Component **DLC_S**	Induced Component **IND_S**	Total Direct Emissions **$OC_S + FC_S + INT_S + DLC_S + IND_S$**	*%*
Land transport	31.94	31.47	124.24	1,180.68	237.42	**1,605.75**	*25.4*
Water transport	3.88	14.61	60.43	1,674.05	224.21	**1,977.18**	*31.3*
Air transport	11.49	4.33	190.24	495.19	62.33	**763.58**	*12.1*
Wholesale and retail trade	226.11	109.72	64.75	794.67	683.28	**1,878.53**	*29.7*
Finance and housing	1.66	0.15	1.39	6.83	1.02	**11.05**	*0.2*
Private and public services	7.93	0.92	4.16	64.91	6.19	**84.10**	*1.3*
Total	283.01	161.22	445.20	4,216.32	1,214.45	**6,320.20**	*100.0*

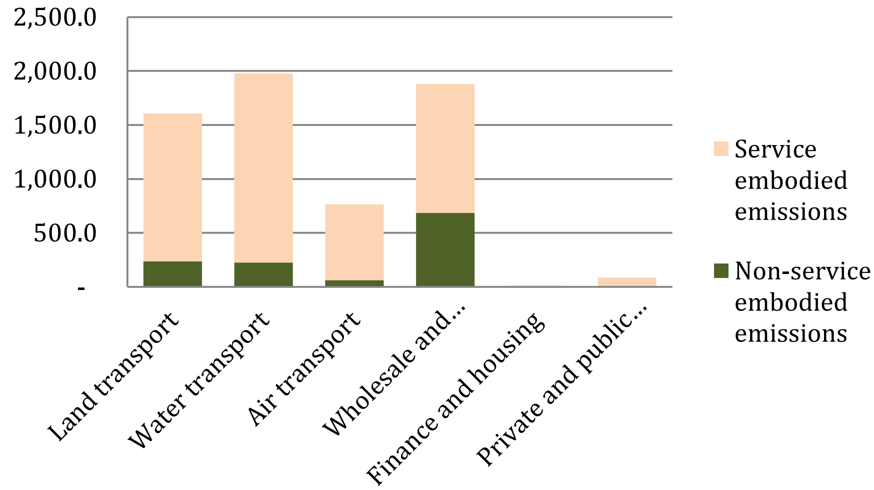
The story changes when the subsystem's emissions are mapped to the actual emissions or the emissions embodied in production, as shown in Table 2. Here, the external component is excluded and replaced by the induced component of emissions. This is because Table 2 accounts for the emissions generated in producing service output regardless of its usage, where some end up as input for producing non-service output, i.e., the induced component. Private services sector drops out as the most significant contributor with water transport and wholesale and retail trade posting the top two actual carbon dioxide emissions given off.

Table 3. Demand decomposition of the CO2 emissions of the service subsystem (kt)					
Service Sectors	Embodied Emissions in Production	Embodied Emissions in Exports	Embodied Emissions in Imports	Embodied Emissions in Trade Balance	Embodied Emissions in Consumption
	EEP^S	**EEE**^{S}	**EEI**^{S}	**EEB**^{S}	**EEC**^{S}
Land transport	1,605.75	343.61	283.60	60.01	1,545.74
Water transport	1,977.18	78.94	3,261.05	(3,182.11)	5,159.30
Air transport	763.58	517.45	1,063.52	(546.06)	1,309.65
Wholesale and retail trade	1,878.53	829.98	805.29	24.68	1,853.85
Finance and housing	11.05	3.16	2.24	0.92	10.13
Private and public services	84.10	19.29	15.53	3.76	80.35
Total	6,320.20	1,792.43	5,431.24	(3,638.81)	9,959.01

Moving on to the demand decomposition, the embodied emissions in production are distinguished from the embodied emissions in domestic consumption. The details are provided in Table 3. Despite being a net exporter of service, the subsystem is surprisingly shown to be a net importer of emissions, having a bigger emissions impact than actual direct emissions. The total embodied emissions in consumption of the service subsystem are almost 60% higher than the embodied emission in production at 9,959 kt.

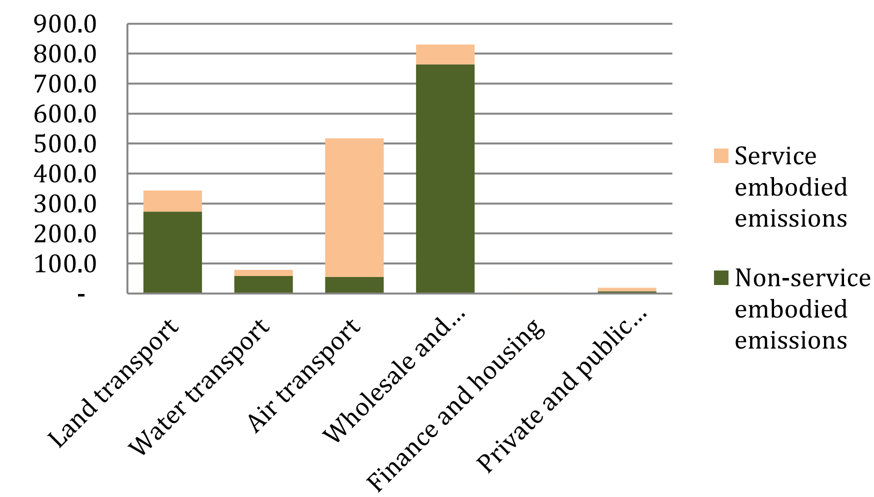
Further, this study allows disaggregation of each demand component of emissions to within-the-subsystem embodied emissions and outside-the-subsystem embodied emissions, more specifically in this case, to service embodied emissions and non-service embodied emissions. These are shown in Figures 1 to 4 for production, exports, imports and consumption, respectively. Apart from embodied emissions in exports, across the demand components water transport consistently appears to have the greatest embodied emissions and most of these are generated for meeting service sector demand. For all the service sectors, the service embodied emissions in production dominate the non-service embodied emissions.

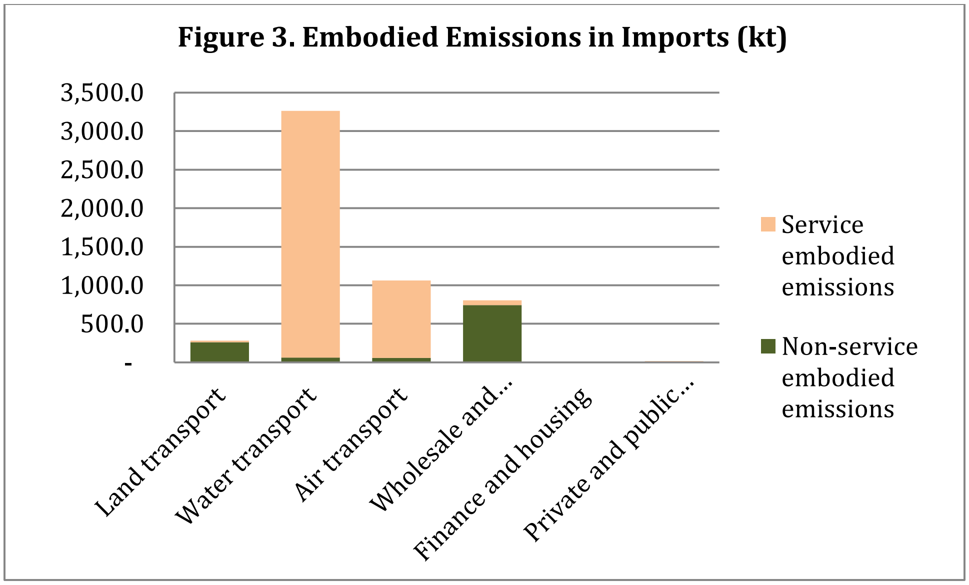
Figure 1. Embodied Emissions in Productions (kt)



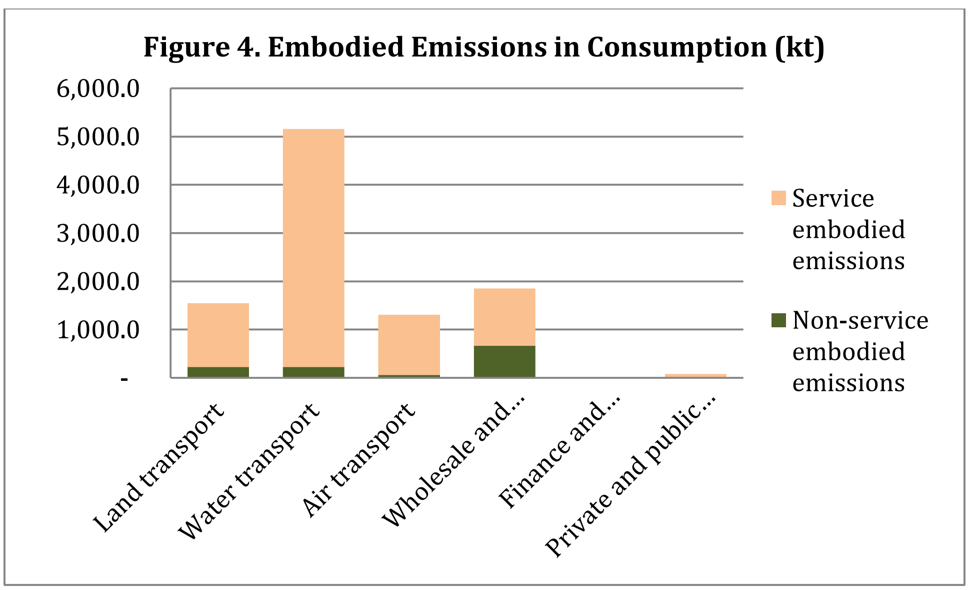
Now, considering the decomposed embodied emissions in international trade, the non-service embodied emissions component appears to be larger for exports especially for wholesale and retail trade, as exhibited in Figure 2. This is more than offset, however, by the bigger within-the-service embodied emissions of imports of water and air transport sectors as shown in Figure 3.

Figure 2. Embodied Emissions in Exports (kt)





Finally, the picture of the distribution of embodied emissions in consumption in Figure 4 appears similar to that of the embodied emissions in production in Figure 1 where the service embodied emissions account for most of them. The difference, of course, is the exceptionally high embodied emissions in consumption of the water transport sector emanating from its net importation of embodied emissions despite posting net exports in terms of output.



5. Concluding Remarks

This study applies the subsystems input-output model in analyzing the carbon dioxide emissions of the Philippine service sector. In the subsystems lingo, the six service sectors are treated as the service subsystem while the rest of the 26 sectors in the Philippine economy are considered the non-service subsystem. It is found that over 65% emissions responsibility of service is due to the use of non-service input in meeting service demand. These may not be direct service emissions but these are generated for the service subsystem. The uncovered significance of the external component, for instance on private and public services, can be a helpful consideration in any policy aimed at emissions mitigation directed on the service sector.

When the emissions responsibility of the service subsystem is reconciled with the direct emissions or the embodied emissions in production of the service subsystem, it is observed that the former is almost 60% larger than the latter. The service sector may appear relatively clean at a glance but a closer look reveals it is responsible for more carbon dioxide than what could be found absent the application of the subsystems input-output analytical framework.

This paper also extends the subsystems input-output analysis via demand decomposition where the embodied emissions in production and in consumption of the service subsystem are distinguished by disaggregating the trade component. The Philippines despite being a net exporter of service turns out to be a net importer of embodied emissions, especially in the water transport sector. This warrants contemplation of a possible intervention in terms of internalization of the negative externality from carbon dioxide emissions of sectors that heavily import embodied emissions. The result of the proposed demand decomposition reveals that most of service's embodied emissions are from within-the-subsystem generated for meeting service demand.

These results may serve as aid for policy makers and other stakeholders in considering policies aimed for the mitigation of Philippine carbon dioxide emissions. Although the country only contributes around 0.3% of world emissions, marginal carbon dioxide reduction remains relevant for this economy that is identified as one of the most vulnerable to the detriments of climate change.

Lastly, this study also highlights the usefulness of the subsystems input-output analysis on shedding light on the impact of any variable of interest that can be related to the production process of the economy, other than carbon dioxide, of a sector or group of sectors.

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