RESEARCH ARTICLE

Environmentally-extended input-output analysis for Malaysia

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Abstract:

Sustainability has become the key goal in every aspect of the environment especially in the diverse urban systems. Sustainable practices require a controlled setting within an urban system where their practicality and efficacy could be assessed. The aim of the study is to establish an environmental assessment tool based on urban metabolism approach to assist decision-making during environmental and economic assessment in an urban planning process. The outcome provides understanding on the means of integrating carbon footprint and monetary factor to oversee the expenditure of a nation in general, or a household or an individual in particular, in relation to global warming potential. This study applied a retrospective cross sectional study to evaluate sustainability in economic-environmental input-output model for greenhouse gases emission monitoring and climate change adaptation. The potential impact from economic sectors' contribution on greenhouse gas emissions which eventually leads to global warming and climate change was quantitatively assessed by examining the contribution of greenhouse gas emission from each economic activity. Malaysia greenhouse gas emission of all 120 economic activities is 4.87 kg CO_2-eq./cap/day. The use of publicly available data to assemble the matrix representation enables comprehensive assessment of the environmental impacts of a country in a manner which is not only of high technology but also relatively fast and cost effective.

Keywords: carbon dioxide emission, economic input-output table

1. INTRODUCTION

Development is often carried out without fully considering the future consequences and creates numerous environmental impacts including increased air and water pollution [1-2], climate alteration [3-4], emergence and re-emergence of disease [5-7], insufficient housing and sanitation facilities [8-9], as well as overcrowding [9-10] and traffic congestion [11-12], which would result in negative environmental ramifications to the cities.

Growth in terms of economy of a country is generally aided by industrial activities which further drive the process of urbanisation. The urban metabolism approach is seen to provide a structured format in specially-designed tools and could identify potential environmental impacts that can be avoided as well as society and environmental benefits that can be enhanced. This study is anticipated to provide a novel environmental assessment by using input-output analysis for national and regional assessment while serving as a platform for enhanced strategic environmental assessment where a suitable and consistent method is applicable across countries and economic sectors. It enables comparison at the local and international level in the evaluation of the environmental impact in line with the mission to improve climate change urban policies and regulations.

2. MATERIALS AND METHODS

The basic understanding in economic input-output table was to see the product branches by lines and columns. The input-output table shows the amount of money paid for each economic sector (lines) to manufacture the products of the other sectors (columns). The most significant part of the Input Output table is to derive the "inverse Leontief" matrix or the matrix $(I-A)^{-1}$. The table can be generated by a spreadsheet software function (Microsoft Excel). The flow of computation along the economic data to environmental outcomes and the step-by-step computation are described in Figure 1. Economic input-input analysis takes into account the monetary fluxes it generates in the total national economy and the average environmental impact of each economic sector in carbon dioxide emissions per currency.

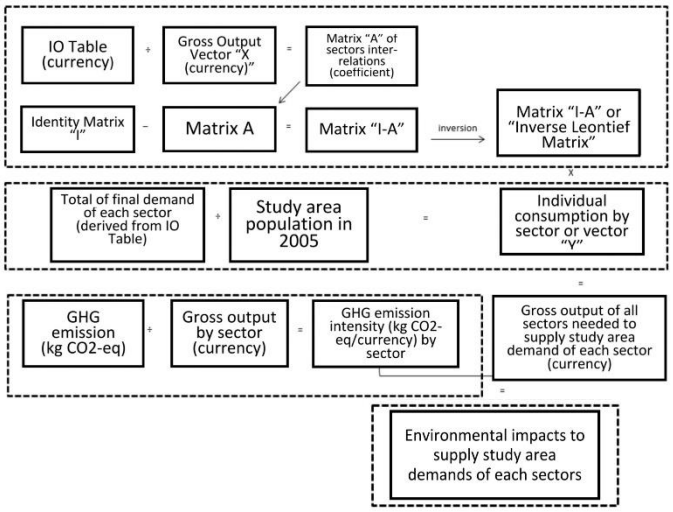


Figure 1. The Flow of Computation for Environmental-Economic Input-Output Model

This exercise provides an understanding on environmental impact assessment because large-scale environmental impacts in a particular area can be studied. Calculation and analysis on greenhouse gas emissions, carbon and water footprints, pollution, and embodied energy can be produced as well.

3. RESULTS AND DISCUSSION

3.1 Individual Consumption

The first co-efficient matrix generated was the individual consumption. The total Malaysian individual consumption via 120 economic activities was RM 33, 021.98 per year. Hence, the crude Malaysian individual consumption per month was RM 2751.83. This finding concurs with the data provided by the Department of Statistics, Malaysia where the average monthly individual income in 2004 was RM 3,250 [13]. This suggested that an average Malaysian purchased higher number of items or services with higher income, indicating that one would have a greater purchasing power as their income increases.

Based on the 120 economic activities, the "semi-conductor devices, tubes and circuit boards" was the highest economic activity with a total individual consumption of RM 3708.18/cap/year. The second highest individual consumption was from the "office, accounting and computing machinery" that contributed RM 3039.69/cap/year followed by "TV, radio receivers and transmitters and associate goods" with RM 2219.48/cap/year. The summary of the top five highest economic activities for Malaysian individual consumption is illustrated in Table 1.

Table 1. The Highest Economic Activities for Malaysian Individual Consumption

No.	Economic activities	Individual consumption (RM/cap/year)	Percentage
1.	Semi-conductor devices, tubes and circuit boards	3708.18	11.23
2.	Office, accounting and computing machinery	3039.69	9.21
3.	TV, radio receivers & transmitters &associate goods	2219.48	6.72
4.	Crude oil and natural gas	1977.66	5.99
5.	Motor Vehicles	1049.41	3.18

Malaysia's electronics industry is leading the manufacturing sector. The production is in high capacity with a variety of semiconductor gadgets, high-end consumer electronic and information and communication technology (ICT) products being manufactured [14]. Semiconductor devices, tubes and circuit boards are produced using silicon and different materials that encourage the controlled conduction of power. The products incorporate memory chips, picture sensors, diodes, transistors, and sun-powered cells. These items are frequently utilised within machines, telecom items, and different electronic gadgets and commonly being used in Malaysia as important tools for communication. The results show that host-site institutional support is more important than regional integration in influencing firms' capacity to upgrade their technological capabilities [15].

Alongside other developing nations, Malaysia is moving towards becoming one of the developed countries in the world where technology enhances profitable revenue to the country. Hence, the use of computers and machines facilitates manpower and provides technical support to the industry. Manufacturing of office, accounting and computing machinery has been the second highest economic activity in Malaysian individual consumption. It is important as it is an ICT-producing activity that provides a large number of investment goods to other sectors [16], [17].

3.2 Individual Consumption Based on Key Categories

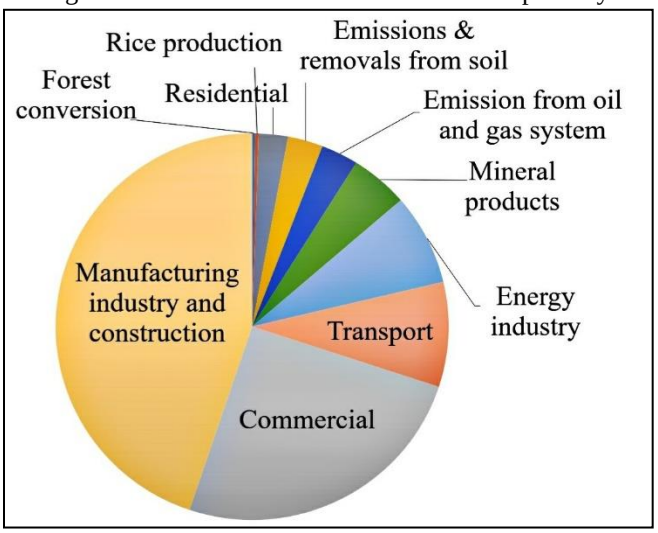
An analysis was also performed in this study to determine the individual consumption by economic activities based on the ten key categories and the results are presented in Table 2. The highest Malaysian individual consumption was in "manufacturing industry and construction" with RM 13,542.90 per capita per year. Malaysia has been developing over the years, enhancing the economic base for the country.

Table 2. Malaysia's Individual Consumption by Ten Key Categories (RM/capita/year).

No.	Economic activities	Individual consumption (RM/cap/year)
1	Forest conversion	71.60
2	Rice production	85.40
3	Residential	731.40
4	Emissions & removals from soil	871.90
5	Emission from oil and gas system	926.90
6	Mineral products	1,438.00
7	Energy industry	2,305.00
8	Transport	2,645.90
9	Commercial	7,588.80
10	Manufacturing industry and construction	13,542.90

The manufacturing industry is seen as the leading boundary of modernisation and skilled job establishment as well as a fundamental source of a mixture of spill over effect [18]. Thus, this industry has been seen as a crucial factor in developing the country. The distribution of individual consumption over economic activities is illustrated in Figure 2.

Figure 2. Distribution of Individual Consumption by



Economic Activities Based on Ten Categories

This can be supported with extensive urbanisation, where the increment of demands and supplies from the industries are indispensable. According to [19] there were relatively young and large working-age populations in the demographic characteristics that could provide support for income growth. It is anticipated that young people tend to spend more on non-essential goods and services, making them a generally high marginal propensity consumers. The least individual consumption by sector was "forest conversion" with RM 71.60 per capita per year.

3.3 Greenhouse Gas Emission Intensity

The findings presented in Table 3 are the factors of greenhouse gas emissions intensity (kg CO_2-eq./RM) for each economic sector. Greenhouse gas emission intensity value is very significant in the case where there is a need to increase production while minimising its influence on climate change. The particular economic sector will need to reduce greenhouse gas emissions per unit of product [20].

Table 3. Summary of Malaysian GHG Emission Intensity in 2005 by Ten Key Categories of Economic Activities

Key category	GHG emission (kt CO_2-eq. / year)	Gross output (RM)	GHG emission intensity (kg CO_2-eq. /RM)
Transport	35587	265520.44	0.134
Residential	1812	15960.69	0.114
Energy industry	58486	1677288	0.035
Forest conversion	24111	1244083	0.019
Rice production	1861	225368.33	0.008
Mineral products	9776	2077312.1	0.005
Commercial	2122	833229.1	0.003
Construction & manufacturing industry	26104	11977942	0.002
Emissions & removals from soil	4638	5302135	0.001
Emission & removals from oil and gas system	4638	2414051	0.001

The computation of greenhouse gases emission intensity is necessary for this study to determine the Global Warming Potential by economic sectors and also to measure the total greenhouse gases emission for a region or a city.

3.4 Impact Assessment

The highest contributor for greenhouse gases emission (GHG) comes from the activities of "crude oil and natural gas sector". "Petroleum refinery" activities come in second followed by "motor vehicle", "office, accounting and computing machinery" as well as "semi-conductor devices, tubes and circuit boards". The summary of greenhouse gases emission for the above activities is shown in Table 4.

The "crude oil and natural gas" category contributes the highest in terms of to Malaysia greenhouse gas emission with 0.732 kg CO_2-eq./day. This is mainly because Malaysia is one of the crude oil producers in the world and ranked 29th in the world concerning crude oil production. Energy is known to be a driver to development. The main energy supply shall be secured together with green energy initiatives [21].

Table 4. Highest Economic Activities in terms of Greenhouse Gas Emission

Economic activities	GHG emission (kg CO_2-eq./day)
Crude oil and natural gas	0.732
Petroleum refinery	0.597
Motor Vehicles	0.501
Office, accounting and computing machinery	0.443
Semi-conductor devices, tubes and circuit boards	0.299

The second highest GHG contributor is the "petroleum refinery" activities with 0.597 kg CO_2-eq./day. Its processes comprising heavy to light hydrocarbon distillation and crude oil separation generate substantial amount of GHG. GHG emission from petroleum refinery directly contributes towards the amount of Global Warming Potential. The third highest contributor to Malaysia GHG emission is from "motor vehicles" activities with 0.501 kg CO_2-eq./day. In 2005, a total of 14,816,407 motor vehicles were registered in Malaysia.

The electrical and electronics industry registered massive growth in exports, thus maintaining Malaysia's position as a net exporter of electrical and electronic products. Malaysia's production and export of semiconductors ranked among the top five in the world during the period between 2000 to 2004. Exports of electronic products by sub-sectors: (i) office, accounting and company machinery; RM 115.4 billion and (ii) semi-conductor devices, tubes and circuit boards; RM 100.4 billion; make "office, accounting and computing machinery" activities the fourth highest GHG emission contributor in Malaysia with 0.443 kg CO_2-eq./cap/day followed by "semi-conductor devices, tubes and circuit boards" with 0.299 kg CO_2-eq./cap/day.

The economic activities linked with their demand are shown in Figure 3.

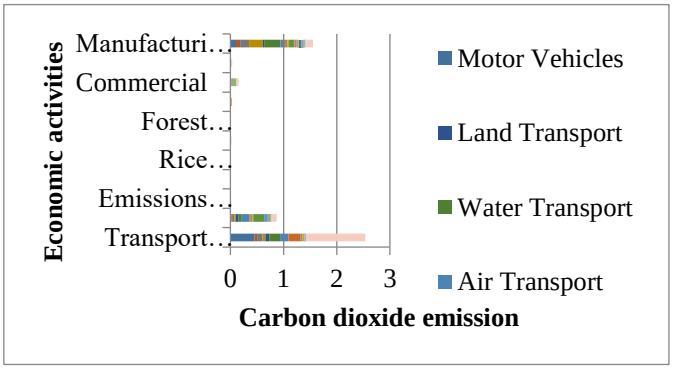


Figure 3. Economic Activities in terms Of Carbon Dioxide Emission for Malaysia

From the analysis, it is shown that the demand for transport and communication creates the highest greenhouse gases emissions (2.536 kg CO_2-eq./cap/day) followed by the manufacturing industries with 1.554 kg CO_2-eq./cap/day. The third highest greenhouse gases emitter is from the energy industry sector with 0.867 kg CO_2-eq./cap/day. In the United States of America, the largest source of its greenhouse gas emissions is "electricity production" which accounted for 31 % of U.S. greenhouse gas emissions in 2013, followed by "transportation" at 27 % [22].

Though the sequence is different, the dominating economic sectors seem to reach an outcome. Energy-related carbon dioxide production accounts for 80 percent of these emissions; mostly from burning coal, oil, and natural gas [22].

3.5 Sensitivity Analysis

Often, household expenditure data refer to the national scale and if the data need to be downscaled to the smaller region such as municipality or city level, some uncertainty may be introduced [23]. Therefore, a sensitivity analysis was undertaken to evaluate the influence of using different estimates of household expenditure. Sensitivity analysis is a methodology in uncertainty analysis and is thus important to both calibration and validation. It investigates if the variation in the output of a model is attributed to the variation of its output [24].

Assumption A: Due to lack of data available from the municipalities, the total amount of taxes collected in each municipality is assumed as the total consumption of goods and services of an individual living in each municipality.

Assumption B: A factor was calculated to provide an assumption in order to determine the GHG emission in each municipality. The GHG emission for each municipality is obtained by multiplying each factors with respect to its municipality with Malaysia GHG emission.

The greenhouse gas emissions at four different municipalities (Putrajaya, Kajang, Shah Alam and Klang) were calculated to provide an overview of the environmental impacts related with the consumption of goods and services in each municipality by using a set of data obtained at national level. These data were downscaled to municipality level, which had introduced some uncertainty. Therefore, a sensitivity analysis was undertaken to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions [25].

The sensitivity analysis provided the weightage to each of the municipalities against the national data. With the designated weightage or factor, the municipality greenhouse gases emissions could be computed and generated. The Malaysia's greenhouse gas emission was then multiplied with these factors to compute the GHG emission in all the four municipalities (Table 5).

Table **Error! No text of specified style in document.**. Sensitivity Analysis of Greenhouse Gas Emission

Key category	GHG emission (kg CO_2-eq./day)				
	Malaysia	Kajang	Putrajaya	Shah Alam	Klang
Weightage factor		1.8	0.5	3.8	3.1
Energy industry	0.823	1.481	0.412	3.1274	2.5513
Transport	1.305	2.349	0.653	4.959	4.0455
Construction and manufacturing industry	1.228	2.210	0.614	4.6664	3.8068
Emission from oil and gas system	0.597	1.075	0.299	2.2686	1.8507
Commercial	0.535	0.963	0.268	2.033	1.6585
Forest conversion	0.005	0.009	0.003	0.019	0.0155
Emissions & removals from soil	0.025	0.045	0.013	0.095	0.0775
Mineral products	0.112	0.2017	0.056	0.4256	0.3472
Rice production	0.002	0.0034	0.001	0.0076	0.0062
Residential	0.238	0.429	0.119	0.9044	0.7378
Total	**4.870**	**8.766**	**2.435**	**18.506**	**15.097**

From the expenditure data at municipal level, Kajang lead the individual expenditure with RM 411.49, followed by Putrajaya (RM 339.85), Shah Alam (RM 293.20) and Klang (RM 195.65). According to [26] Putrajaya recorded the highest mean monthly household consumption expenditure (RM 5,627), followed by Kuala Lumpur (RM 5,559) and Selangor (RM 4,646).

The mean monthly household consumption expenditure for Malaysia increased from RM 2,190 in 2009 to RM 3,578 in 2014 which was 9.8% per annum at the nominal value. While at a real value, the annual growth rate is 7.5% for the same period. The mean monthly household consumption expenditure in urban area showed an increment at a rate of 9.3% annually from RM 2,465 to RM 3,921 while in rural also increased at a rate of 8.4% annually from RM 1,599 to RM 2,431 for the period of 2009 to 2014.

4. CONCLUSION

This study has explained the formulation of the environmentally extended input-output analysis. The purely economic input-output table has given out some significant variables and outputs when appropriately expanded with environmental datasets. The initial economic data in terms of input-output transactions coupled with greenhouse gases emission inventory could derive greenhouse gases emission for each economic activities. It also allows analysis particularly in supply chain, improving on the results or assisting to identify errors. The use of publicly available data to assemble the matrix representation enables comprehensive assessment of the environmental impacts of a product or service with effective cost, time and manner.

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