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15 January 2013

Identification of the "Key" Sectors Producing CO_2 Emissions in Malaysia: Application of Input–Output Analysis

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Abstract

An important challenge for many countries in the quest toward a low carbon economy is the identification of the "key" economic sectors that are responsible for CO_2 emissions and what policy initiatives might be appropriate to address these emissions taking into account the role played by the different productive sectors and their relationship with other sectors and atmospheric pollution. This paper applies the Input–Output analysis to identify the key economic sectors producing CO_2 emissions in Malaysia from the production perspective. It allows us to identify the sectors that deserve more consideration for mitigation policies. Results indicate the primary key sectors that demonstrated strong distributive and total effects were dominated by the energy industry and transportation sectors. The choice of demand-or supply-side measures to mitigate the CO_2 emissions is deliberated at the end of the paper.

KEYWORDS: Emission elasticities for Malaysia; Malaysian Input–Output analysis; Malaysian key sectors in carbon emissions; Carbon emission mitigation

JEL CODES; D57, Q54, Q43

Introduction

In light of global climate change issues, most countries of the world including Malaysia are attempting to reduce the amount of CO_2 emission generated from their economic activities. Malaysia made a voluntary pledge in the 2009 COP15 in Copenhagen to reduce her CO_2

emission-GDP intensity by up to 40% by 2020 relative to the 2005 baseline. In this regard, the government is considering several policy options such as environmental standards, carbon taxation, energy efficiency, land use changes, and development of her renewable energy industry.

Given the economy-wide effects that any emission mitigation entails, it is essential to identify the key sectors in CO_2 emission and the inter-relationship between economic sectors. For example, a relatively small number of sectors whose first impulse may produce small emission changes may ultimately affect substantially both the economy and the environment as a whole, or vice versa. Further, it is important to establish whether any economic sector is a polluter through its own production process, or if it is key because it encourages other sectors to produce outputs or intermediate inputs that have such consequences. Therefore, sectors with different level and kind of linkages deserve different kind of policy intervention. Zhang et al., [1] for instance, illustrate that the traditional way of analyzing energy consumption and hence emissions, which emphasizes on direct energy consumption, disregards the complex inter-sectoral energy flows and is insufficient for making robust energy policies.

An important challenge for Malaysia in the quest toward a low carbon economy is the identification of the major economic sectors that are responsible for CO_2 emissions and what policies might be appropriate to mitigate these emissions. A useful approach is to examine the inter-sectoral linkages in terms of CO_2 emissions as the economy grows. From such an analysis, the economic sectors with negative performance, the so-called "key"[1] sectors can be known.

[1] Following Alcantara and Padilla [2], we use the term key in this paper to denote that it is not identical with the same term that is typically used in the input–output literature.

Specifically, knowledge of key sectors is useful to understand how they are inter-related and what emission reduction initiatives will be implemented.

It is also important to note that knowledge of inter-sectoral linkages in carbon emission may not be essential should emission trading or caps on emission is imposed across all sectors in the economy. In such a situation, industries simply identify the efficient emission level or total pollution abatement according to their respective marginal abatement cost. However, development of the local carbon market for a domestic carbon trading scheme may not very likely to happen in Malaysia in the near future due to the sophistication of such instruments and the lack of experience in the use of economic instruments in managing her natural environment.

The basis for the identification of the concept of "key sectors" goes back to Rasmusen [3] and Hirschman [4]. They suggested the use of an input–output (I–O) framework to measure the structural interdependence through backward and forward inter-sectoral linkages, arguing that economic development and structural change are driven primarily by sectors with above-average inter-linkages. Consequently, the identification of key sectors was developed and was determined by the multiplier effects of final demand, i.e., from a demand-driven perspective. Such a procedure forms the bulk of input–output analysis in the literature.

Departing from the traditional application of I–O analysis, Hayami et al. [5] developed a procedure on how the I–O analysis can be used to estimate the production and consumption of greenhouse gases, conditional on production technology and consumer preferences. Alcantara and Padilla [6] proposed an I-O methodology for the determination of the key sectors responsible for CO_2 emissions from the final energy consumption side.

More recently, Alcantara and Padilla [2] developed an I–O methodology that enables the identification of the key sectors from the supply perspective and applied it to the Spanish economy. While the original key sectors developed by Rasmussen and Hirschman were primarily driven by demand, the determination of key sectors in Alcantara and Padilla [2] is value-added driven. The latter framework has gained increasing attention, as reflected in the works of Tarancon and Rio [7], Reyes[8], and Jodar [9], among several others.

The Malaysian Department of Environment stated in its special report on air pollution that power stations, motor vehicles and open burning are the main contributors to the country's growing emissions [10]. However, the report simply states the key sectors in CO_2 emissions are based on the quantum of direct emissions. Such a definition ignores the interaction of a particular sector with the other sectors of the economy, and only considers the emission from direct or first level impulse. As aforementioned, some sectors may produce relatively small emissions directly, however, they may ultimately lead to strong emission effects in the economy via the use of its outputs by other sectors. Therefore, to reduce CO_2, it is important that the key sectors of the Malaysian economy are identified through an appropriate procedure. To date such studies have not been attempted for Malaysia.

This study applies the method as developed by Alcantara and Padilla [2] to the case of Malaysia. It implements an I–O analysis from the production perspective and computing the income elasticity of emissions to establish the key sectors. This forms the basis to devise

appropriate CO_2 reduction initiatives in light of the country's pursuit to move toward a greener economy.

Materials and Methods

The key sectors in CO_2 emissions were identified by calculating the emission elasticities that describe the relationship between CO_2 emissions and the income generated in the country.

Following closely the notations and frameworks used in Alcantara and Padilla [2], for an n-sector economy let x be the $nx1$ vector of total productions and v be the $nx1$ vector of value added in the I–O absorption matrix. A is the nxn matrix of technical coefficient, with the a_{ij} referring to the use of input i in the production of output j. Notation u is the $nx1$ unitary vector, while $s$is an$nx1$ vector of value added coefficients with characteristic elements $S_j = \frac{v_j}{x_j}$. Scalar C denotes the total level of CO_2 emission, while c is a $nx1$ vector of direct CO_2 emissions from each sector, g is a $nx1$ vector of the distribution of total emissions among the productive sectors with the characteristic element of $g_i = \frac{c_i}{C}$ where $\sum_{i=1}^{n} g_i = 1$. The *hat* notation shows the identification of a vector in a square matrix where its principal diagonal is the element of the vector and off diagonal elements are zeroes. Further, the prime notation (') refers to a transposed vector or matrix.

From the supply perspective, the system of n linear equations shows that the total production is equal to the sum of intermediate inputs and the value added:

$$x = \hat{x}A'u + v \qquad (1)$$

By pre-multiplying both sides of (1) by $\hat{x}^{-1}$, we obtain equation 2:

$$u = A'u + s \qquad (2)$$

Rearranging (2) and solving it for u will yield the following form:

$$u = (I - A')^{-1}s \qquad (3)$$

Let c be a vector of sectoral direct CO_2 emissions as previously defined; by pre-multiplying both sides of (3) with $\hat{c}$, we will obtain

$$c = \hat{c}(I - A')^{-1}s \qquad (4)$$

Considering that $c = Cg, \qquad (5)$

by plugging (5) into (4), we obtain

$$c = C\hat{g}(I - A')^{-1}s \quad (6)$$

By pre-multiplying both sides of (6) byu', the sectoral emission (c) in the left-hand side will be translated to the scalar (C), while the right-hand side remains unchanged:

$$C = Cg'(I - A')^{-1}s \qquad (7)$$

Any proportional increase in the value added ($\propto = \frac{\Delta v_j}{v_j}$) would increase the total amount of emissions by ΔC, as shown in equation (8):

$$\Delta C = Cg'(I - A')^{-1}s \propto \qquad (8)$$

Dividing both sides of equation by C yields

$$\frac{\Delta C}{C} = g'(I - A')^{-1}s \propto \qquad (9)$$

By the diagonalization of s in Eq.9 and assuming $\propto = 1\%$, we have

$$\epsilon_i' = g'(I - A')^{-1}\hat{s} \qquad (10)$$

Here, ϵ_i denotes the elasticities that reflect the proportional change in emissions from a percentage change in the value added or income of sector j. It is also known as the income elasticity of emissions. The characteristic element ofϵ_i is written as follows:

$$\epsilon_i = \frac{\frac{\Delta C}{C}}{\frac{\Delta v_j}{v_j}} \qquad (11)$$

High emission elasticity indicates the level of CO_2 emissions is highly responsive to changes in the value added generated by the respective sector.

For greater flexibility of interpretation, the g' is diagonalized such that Eq.9 becomes

$$E^v = \hat{g}(I - A')^{-1}\hat{s} \qquad (12)$$

The characteristic element of E^v denoted by E_{ij}^v shows the percentage change in the emission of sector i due to a 1% increase in the income (value added) generated in sector j.

The total impact of an increase in the value added of sector j in the economy is measured by summing the elements over the i row (column sum), $\sum_{i=1}^{n} E_{ij}^{v} \ \forall j = 1, \dots, n$. This expression explains the percentage change in total CO_2 emissions in response to a 1% increase in the value added generated by sector j.

On the other hand, the sum of the elements over j, $\sum_{j=1}^{n} E_{ij}^{v} \ \forall i = 1, \dots, n$, indicates the distributive effect of a 1% change in the overall value added (national income) on the emissions generated by the i^{th} sector.

Following Tarancon and Del Rio [7], the relevant sectors in CO_2 emissions are identified based on the rescaled elasticities. This is done by using the following formulae:

$$\frac{\sum_{i=1}^{n} E_{ij}^{v}}{\frac{\sum_{j}^{n}\sum_{i}^{n} E_{ij}^{v}}{n}} * 100 \qquad (13) \qquad \text{and} \qquad \frac{\sum_{j=1}^{n} E_{ij}^{v}}{\frac{\sum_{i}^{n}\sum_{j}^{n} E_{ij}^{v}}{n}} * 100 \qquad (14)$$

A value of higher than 100 in both equations (13) and (14) makes the sector a key sector in CO_2 emissions. These sectors require close policy scrutiny as their sectoral growth and/or overall economic growth would induce higher emissions. Hence, such sectors offer greater opportunities for environmental improvement or CO_2 mitigation.

Input–Output Table and Sectoral Aggregation

In this study, the 120-sector industry I–O transactions table for Malaysia for the year 2005 published by the Department of Statistics (2011) [11] is aggregated into 35 sectors. However, the energy holder sectors are maintained. The energy holder sectors are "other wood products," "crude oil and natural gas," "petroleum refinery," "electricity and gas," and "waterworks." Table (A-1) shows the aggregation of the 120 old sectors into the 35 new sectors.

Constructing the Vector of Sectoral Emissions

We first estimated the amount of fuel consumption for each sector in physical units. Table 1 (top row) provides the share of each fuel type used for combustion for the different aggregate sectors.

The refined petroleum product (row 3 of Table 1) is further disaggregated to capture the more specific types of fuel. The type of fuel and its share with respect to total use of refined petroleum product is shown in Table 2. Note that due to the lack of data we did not disaggregate the "diesel oil" category into industrial diesel oil and automotive diesel oil. However, the price index and emission coefficients represent the average of the two categories.

The aggregated I–O in monetary value is converted into quantities by using the average price of each fuel for the year 2005.The data on the average price of fuel is synthetic in the sense that some of them are taken directly from secondary sources and some are calculated by dividing the value of fuel sold to the domestic economy by the quantity of fuel used. The second column of Table A-2 shows the average price for each fuel. Such prices may encompass transportation and commercial margins and would tend to underestimate the quantity of fuel used. Nevertheless, by presuming a fixed proportion of margins across sectors, the order of fuel consumption will be preserved and the reliance on the purchased price of fuels may not alter the resulting emission elasticity estimates significantly.

Table A-2 provides estimates of CO_2 emissions for a given unit of fuel. To translate the amount of energy used into emissions, the emission factor is multiplied by the quantity of fuel consumed for each activity. Table 3 shows the amount of CO_2 generated by each activity and their share of the total emissions produced from the production side of the economy.

Table 4 ranks the top 15 producers of CO_2 emissions in the country. As shown in bold, the Transportation sector (29), followed by Petroleum Refinery (15), and Electricity and Gas (24) are the largest emitters of CO_2 among the productive sectors. These 15 sectors contributed 91% of total emissions.

Petroleum Refinery, Electricity and Gas, and Mining are energy and power-related sectors. By considering these sectors as one aggregate energy industry or power sector, it turns

out to be the top CO_2 emitter at 32%, followed by Transportation at 16%. The Malaysian NC2 report also indicates that the largest emitter was the energy industries, followed by the transportation and manufacturing industries. The cement industry is an important emitter of carbon in Malaysia; however, our paper focuses on the CO_2 emission from the combustion of fuel only, excluding industrial processes.

Results and Discussions

We now present the results of the I–O analysis to establish the key sectors for CO_2 emission in Malaysia. Evaluation of the key sectors involves delving into the details of the elasticity matrix as depicted in Table A-3. The relevant elasticities (shown by 1) are obtained after filtering out the low elasticity values (less than the rounded value of 0.001).

Table 5 shows the computed elasticities and indices, namely the total impact, the distributive impact, and their corresponding rescaled values. Based on the rescaled elasticities (above 100), the key sectors are ranked and shown in Table 6 and 7.

The distributive effect signifies the percentage change in total emissions in the economy in response to a 1% change in the country's national income. The distributive impact (Table 6) is dominated by;

- Mining (4)
- Petroleum Refinery (15)
- Transportation (29)
- Electricity and Gas sector (24)

- Basic Chemicals, Fertilizers and Tires (16)

Note the strong dominance of the aggregate energy industry and power sector (sectors 4, 15 and 24).

The total impact reflects the percentage change in total emissions in the economy given a1% increase in the value added of the respective sector. The ranking of related sectors is as follows (Table 7):

- Mining
- Petroleum Refinery
- Transportation
- Basic Chemicals, Fertilizers and Tires
- Plastic and other Chemical Products
- Other Manufacturing
- Manufacture of Metal Products
- Wholesale, Retail Trade, Hotel and Restaurant

Primary sectors are defined as those sectors that are significant in both the distributive and total effects, i.e. these effects are equal or higher than 0.001.The key primary sectors are responsible for 0.7% of the total increase in emission given a 1% increase in the overall income (GDP), while a 1% increase in the respective value added induces a 0.80% increase in total emissions attributed to these sectors. This means the key primary sectors are responsible for 70% of distributive effects and 80% of total emission effects.

For the sectors that demonstrate higher distributive effects than total impacts, overall economic growth provokes greater emissions relative to the growth in sectoral value added. The Mining sector particularly displays the most pronounced distributive effect due to derived demand from other user sectors.

For those sectors showing higher total effect than distributive effect (all key sectors except Mining), the increase in sectoral value added induces more CO_2 emissions than that of a proportionate increase in GDP.

Secondary key sectors are defined as those sectors that are significant, i.e. having a value of equal or higher than 0.001 in either the distributive or total effect but not on both effects. Table A-3 identifies the key sectors by showing the relevant direct and indirect elasticities, with a rounded value of equal or more than 0.001 used as a filter. These elasticities show the intersectional productive and emission linkages. The cells in the rows denote the supplier sectors that stimulate CO_2 emissions from sector *i* while the columns signify the user sectors that indirectly generate CO_2 emissions for sector *j*. Appendix A4 summarizes the emission impacts from income generation for each sector including other pertinent results.

Based on the scaled elasticities and filtering criteria, the secondary key sectors are:

- Other Agriculture
- Construction
- Banking and Housing.

These sectors are responsible for about 10% of distributive impacts and almost 4% of total effects.

Our I–O analysis suggests the following sectors are key primary areas in CO_2 emissions:

- Mining
- Petroleum Refinery
- Transport
- Electricity and Gas
- Basic Chemicals, Fertilizers and Tires
- Plastic and other Chemical Products
- Other Manufacturing
- Manufacture of Metal Products
- Wholesale, Retail Trade, Hotels, and Restaurants

These sectors are associated with a 0.70% increase in distributive emission given a 1% increase in overall value added (GDP), while a 1% increase in the income (value added) of the respective sector provokes an increase of 0.80% in total emissions. In the context of inter-sectoral linkages, the emission effects from the key primary sectors are attributed to both the user and supply sectors. The key secondary areas are Agriculture, Construction, and Banks and Housing.

A combination of both the primary and secondary sectors is responsible for about 80% of distributive emissions impact and almost 82% of total effect in the economy (see Table A-4).

The following primary areas exhibit greater total effects;

- Petroleum Refinery
- Electricity and Gas
- Transport
- Basic Chemicals, Fertilizers, and Tires
- Plastic and Other Chemical Products
- Wholesale, Retail Trade, Hotels, and Restaurants

Emissions from these sectors are more likely to be self-generated, being induced more by sector-specific supply factors that led to own value added economic growth. Therefore, initiatives targeting the production side (such as economic incentives that induce the use of energy-saving technologies) are the more appropriate measures for low CO_2 emissions. Production-side measures and incentives are also recommended for the Construction sector, which is a secondary key sector due to the significant total effect.

Mining, Manufacture of other Metal Products, and Other Manufacturing are significant due to their extensive upstream and downstream linkages. A combination of demand and supply side regulations is recommended while more focus should be given to demand-side policies.

Mining, Agriculture, and Banks and Housing show the dominance of indirect effects attributed to the user sectors (Table A4). Demand-side management or user-focused strategies are most appropriate to mitigate carbon emissions for such sectors. The main aim is to induce a

sustained user behavioral change toward more efficient use of energy. Subsidized energy is the most important barrier to effective demand side management. Hence energy subsidy removals would constitute a key strategy.

Other broad strategies include energy audits, labeling, regulations, and economic instruments such as incentives (for development and procurement of efficient technologies), carbon or environmental taxes and tradable emission permits in the longer-run. Table 8 outlines the various key sectors along with the possible initiatives for CO_2 mitigation.

Conclusions

This study has identified the key economic sectors that are responsible for CO_2 emissions in Malaysia. Results indicate the primary key sectors were dominated by the energy industry and transportation sectors. The choice of demand-or supply-side measures to mitigate the CO_2 emissions was deliberated. This study demonstrates clear support to the ongoing efforts undertaken by Malaysia especially on greater development of renewable energy via the implementation of the Feed in Tariff (FiT) framework, pursuance of demand-side strategies, and improvement in energy efficiency for the key sectors. Development of the renewable energy sector as well as improvements in energy efficiency will not only mitigate emissions but they produce a host of co-benefits in terms of environmental improvements as well as sustaining the energy needs of the country in the long run.

This study did not attempt to identify the nature of economic agents or producers in each key sector. Whether each sector is dominated by domestic firms or multinationals that are

sensitive to any environmental regulations is beyond the scope of this study. The focus has been on the identification of the key sectors and the likely initiatives that can be deliberated by the government to reduce carbon emissions and the reliance on unsustainable fossil fuels for sources of energy in the long run. The implementation intricacies including the issue of public acceptance and appraisals of cost effectiveness or benefits-costs analysis may be a subject of further research.

It is also important to note that the analysis of "key sectors" and inter-sectoral linkages in carbon emission as espoused in this paper implies that certain mitigation strategies such as emission trading and overall carbon caps may not be a relevant policy choice. This is because these strategies presume that industries rely on their respective marginal abatement cost in deciding their efficient level of emission and thus overall total abatement cost will be minimized. Further, this paper only discusses CO_2 emissions from fossil fuel combustion and not from other activities such as industrial processes, land use changes and agriculture. As a result, the actual key economic sectors producing overall CO_2e in Malaysia, might not be the ones identified in this paper. Future studies are warranted to estimate the carbon equivalent emissions from all economic sectors in an input-output framework to generate more representative results.

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Table 1: Share of each fuel kind with respect to energy groups for different activities (2005).

Commodities	Commodity	Total Agriculture	Mining & Quarrying	Manufacturing	Construction	Transport	Other Services	Total
Manufacture of charcoal	Manufacture of charcoal	-	-	1	-	-	1	1
Crude oil and natural gas	% crude oil	-	-	0.293	-	-	-	0.293
	% natural gas	-	-	0.707	-	-	-	0.707
Petroleum refinery	% refined petroleum product	1	1	1	1	1	0.996	0.9997
	% processing of nuclear fuel	0	0	0	0	0	0.004	
Electricity and gas*	% electricity	0.997	0.997	0.997	0.997	0.997	0.997	0.997
	% gas	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Water works	% steam and hot water supply	0	0	0	0.010	0.402	0.027	0.034
	% collection, purification and distribution of water	1	1	1	0.990	0.598	0.973	0.966

Source: Calculated from raw data provided by Department of Statistics Malaysia (DOS) [12]
*Disaggregation of electricity and gas is based on the structure of the economy in year 2000

Table2: Breakdown of consumption of refined petroleum product for Malaysia (2005)

Petroleum product	Share
Petrol	0.356
Diesel	0.360
Fuel oil	0.076
Kerosene	0.010
Liquefied petroleum gas	0.085
ATF&AV GAS	0.091
Non Energy	0.022
Total	1

Source: Calculated from the National Energy Balance of Malaysia, 2005 [13]

Table 3: CO_2 emitted from each productive sector in tonnes (2005)

	Sector	CO_2 emission (tonnes)	Share
1	Other Agriculture	891288	0.0083
2	Flower Plants	75	0
3	Fishing	336986	0.0031
4	**Mining**	**7115815**	**0.0661**
5	Other Mining and Quarrying	564974	0.0052
6	Other Food and Beverages	956331	0.0089
7	Food and Beverages Except Grain Mills	2334793	0.0217
8	Grain Mills	202566	0.0019
9	Tobacco Products	76508	0.0007
10	Textile and Wearing Apparel	629984	0.0058
11	Leather Industries and Footwear	7459	0.0001
12	Printing, Paper Product, Furniture and Other Wood Product	852213	0.0079
13	Wood Products	998463	0.0093
14	Publishing, Paints and Varnishes	68179	0.0006
15	**Petroleum Refinery**	**16172261**	**0.1501**
16	Basic Chemicals, Fertilizers and Tyres	10833884	0.1006
17	Plastic and Other Chemical Product	7265085	0.0674
18	Manufacture of Rubber Products	1780411	0.0165
19	Glass Product, Clay and Ceramic	2142150	0.0199
20	Cement Manufacture, Concrete & Other Non Metallic Mineral Products	2953894	0.0274
21	Manufacture of Metal Product	4236733	0.0393
22	Manufacture of Machinery/Equipments	562653	0.0052
23	Other Manufacturing	3605095	0.0335
24	**Electricity & Gas**	**12556950**	**0.1166**
25	Waterworks	368863	0.0034
26	Construction	3123907	0.029
27	Special Trade Works	565059.3	0.0052
28	Wholesales, Retail Trade, Hotels and Restaurants	4492370	0.0417
29	**Transport**	**17657886**	**0.1639**
30	Port and Airport Operation Services	48205	0.0004
31	Other Transport and Communication	580221	0.0054
32	Banks and Housing	13.63451	0
33	Other Finance and Housing	888260	0.0082
34	Other Business and Private Services	854926	0.0079
35	Business, Private and Government Services	1988611	0.0185
	Total[+]	107713079	1

Source: Author's calculations

[+] *The official estimates for overall green house gases for 2005 as stated in the Malaysian Second National Communication (NC2) to the UNFCCC Report [14] were 204 million tons, of which some 65% were composed of CO_2 emissions from the use of fossil fuel only (Ministry of Natural Resources and Environment, 2010). Thus our estimates in this paper represent 81% of the official estimates. The smaller estimates are reasonable as this study captures emissions from the production side only while the NC2 report includes emissions from the demand side as well.*

Table 4: Ranking of top emitters

Ranking	Sector No.	Sector	Tonnes (CO_2)	Share	Cumulative Share
1	**29**	**Transport**	**17657886**	**0.1639**	**0.1639**
2	**15**	**Petroleum Refinery**	**16172261**	**0.1501**	**0.3140**
3	**24**	**Electricity & Gas**	**12556950**	**0.1166**	**0.4306**
4	16	Basic Chemicals, fertilizers and tyres	10833884	0.1006	0.5312
5	17	Plastic and Other Chemical product	7265085	0.0674	0.5986
6	**4**	**Mining (largely crude oil)**	**7115815**	**0.0661**	**0.6647**
7	28	Wholesale, retail trade, hotel and restaurants	4492370	0.0417	0.7064
8	21	Manufacture of Metal Product	4236733	0.0393	0.7457
9	23	Other Manufacturing	3605095	0.0335	0.7792
10	26	Construction	3123907	0.0290	0.8082
11	20	Cement Manufacture,Concrete & Other Non Metallic Mineral Products	2953894	0.0274	0.8356
12	7	Food and Beverages except grain mills	2334793	0.0217	0.8573
13	19	Glass Product, Clay and Ceramic	2142150	0.0199	0.8772
14	35	Business, Private and Government Services	1988611	0.0185	0.8957
15	18	Manufacture of Rubber Products	1780411	0.0165	0.9122

Table 5: Impact elasticities and scaled effects

	Sector	Distributive Effect	Total Effect	Scaled Distributive Effect	Scaled Total Effect
1	**Other Agriculture**	**0.0435**	**0.0083**	**152**	**29**
2	Flower Plants	0.0008	0.0000	3	0
3	Fishing	0.0034	0.0031	12	11
4	**Mining**	**0.1714**	**0.0661**	**600**	**231**
5	Other Mining and Quarrying	0.0059	0.0052	21	18
6	Other Food and Beverages	0.0054	0.0089	19	31
7	Food and Beverages except grain mills	0.0175	0.0217	61	76
8	Grain Mills	0.0015	0.0019	5	7
9	Tobacco Products	0.0010	0.0007	3	2
10	Textile and Wearing Apparel	0.0049	0.0058	17	20
11	Leather industries and footwear	0.0002	0.0001	1	0
12	Printing, Paper Product, furniture and Other wood Product	0.0123	0.0079	43	28
13	Wood Products	0.0046	0.0093	16	32
14	Publishing, paints and Varnishes	0.0020	0.0006	7	2
15	**Petroleum refinery**	**0.1063**	**0.1501**	**372**	**525**
16	**Basic Chemicals, fertilizers and tyres**	**0.0613**	**0.1006**	**215**	**352**
17	**Plastic and Other Chemical product**	**0.0545**	**0.0674**	**191**	**236**
18	Manufacture of Rubber Products	0.0143	0.0165	50	58
19	Glass Product, Clay and Ceramic	0.0137	0.0199	48	70
20	Cement Manufacture ,Concrete & Other Non-Metallic Mineral Products	0.0166	0.0274	58	96
21	**Manufacture of Metal Product**	**0.0418**	**0.0393**	**146**	**138**
22	Manufacture of Machinery/Equipments	0.0142	0.0052	50	18
23	**Other Manufacturing**	**0.0456**	**0.0335**	**160**	**117**
24	**Electricity & Gas**	**0.0742**	**0.1166**	**260**	**408**
25	Waterworks	0.0068	0.0034	24	12
26	**Construction**	**0.0235**	**0.0290**	**82**	**102**
27	Special Trade Works	0.0078	0.0052	27	18
28	**Wholesale, Retail Trade, Hotels and Restaurants**	**0.0371**	**0.0417**	**130**	**146**
29	**Transport**	**0.1037**	**0.1639**	**363**	**574**
30	Port and Airport Operation Services	0.0020	0.0004	7	2
31	Other Transport and Communication	0.0254	0.0054	89	19
32	**Banks and Housing**	**0.0357**	**0.0000**	**125**	**0**
33	Other Finance and Housing	0.0075	0.0082	26	29
34	Other Business and Private Services	0.0117	0.0079	41	28
35	Business, Private and Government Services	0.0218	0.0185	76	65
	Total	1.0000	1.0000		
	Average	0.0286	0.0286		

Source: Author's elaboration

Table 6: Ranking of distributive impact

Ranking of Sector	Sector No.	Sector	Distributive Impact	Scaled Distributive Effect	Cumulative Distributive Effect
1	4	Mining	0.1714	600	0.17
2	15	Petroleum Refinery	0.1063	372	0.27
3	29	Transport	0.1037	363	0.38
4	24	Electricity & Gas	0.0742	260	0.45
5	16	Basic Chemicals, Fertilizers and Tyres	0.0613	215	0.51
6	17	Plastic and Other Chemical product	0.0545	191	0.57
7	23	Other Manufacturing	0.0456	160	0.61
8	1	Other Agriculture	0.0435	152	0.66
9	21	Manufacture of Metal Product	0.0418	146	0.70
10	28	Wholesale, Retail Trade, Hotel and Restaurants	0.0371	130	0.73
11	32	Banks and Housing	0.0357	125	0.77

Table 7: Ranking of total impact

Ranking of Sector	Sector No.	Sector	Total Impact	Scaled Total Effect	Cumulative Total Effect
1	29	Transport	0.1639	574	0.16
2	15	Petroleum Refinery	0.1501	525	0.31
3	24	Electricity & Gas	0.1166	408	0.43
4	16	Basic Chemicals, Fertilizers and Tyres	0.1006	352	0.53
5	17	Plastic and Other Chemical Product	0.0674	236	0.59
6	4	Mining	0.0661	231	0.66
7	28	Wholesale, Retail Trade, Hotel and Restaurants	0.0417	146	0.70
8	21	Manufacture of Metal Product	0.0393	138	0.74
9	23	Other Manufacturing	0.0335	117	0.77
10	26	Construction	0.029	102	0.80

Table 8: Key sectors and policy approaches

Sector Codes	Key Sectors (Primary and Secondary)	Dominant Effect [T = Total Effect; D = Distributive Effect]	Policy Orientation [Production = P; Demand = Dd]	Likely Initiatives for Carbon Mitigation
4	Mining	**D**	**Dd**	Reduced subsidies, Tariff increases, Behavioral change, Goal setting, Product innovations
15	Petroleum Refinery	**T**	**P**	Incentives for investments in energy savings or efficiency
16	Basic Chemicals, fertilizers and tyres	**T**	**P**	Incentives for energy efficiency, Energy/emission taxes
17	Plastic and Other Chemical product	**T**	**P**	Incentives for energy efficiency, Energy/emission taxes
21	Manufacture of Metal Product	**-**	**P and Dd**	Mixture of demand and supply side strategies
23	Other Manufacturing	**-**	**P and Dd**	Mixture of demand and supply side strategies
24	Electricity & Gas	**T**	**P**	Incentives for development of REs
28	Wholesale, Retail Trade, Hotels and Restaurants	**T**	**P**	Standards, Incentives for energy efficiency
29	Transport	**T**	**P**	Technology innovation, Standards, Emission and/or energy taxes
1	Agriculture	**D**	**Dd**	Behavioral change, Labeling, Standards
26	Construction	**T**	**P**	Standards, Labeling, Emissions and/or energy taxes
32	Banks and Housing	**D**	**Dd**	Technology innovations, Goal setting, Behavioral change, Energy audits, Labeling

APPENDICES

Table A-1: Sectoral Aggregation

Aggregated Sectors	*New Code*	*Basic Sectors (sector code)*
Other Agriculture	1	Paddy (1), Food Crops (2), Vegetables (3), Fruits (4), Rubber (5), Oil Palm (6), Other Agriculture (8), Poultry Farming (9), Other Livestock (10), Forestry and Logging (11).
Flower Plants	2	Flower Plants (7)
Fishing	3	Fishing (12)
Mining	4	Crude Oil and Natural Gas (13), Metal Ore Mining (14)
Other Mining and Quarrying	5	Stone Clay and Sand Quarrying (15), Other Mining and Quarrying (16)
Other Food and Beverages	6	Meat and Meat Production (17), Preservation of Seafood (18), Preservation of Fruits and Vegetables (19), Dairy Production (20), Other Food Processing (21), Soft Drink (22)
Food and Beverages Except Grain Mills	7	Oils and Fats (21), Bakery Products (23), Confectionery (24), Animal Feeds (26), Wine and Spirit (27)
Grain Mills	8	Grain Mills (22)
Tobacco Products	9	Tobacco Products (29)
Textile and Wearing Apparel	10	Yarn and Cloth (30), Finishing of Textiles (31), Other Textiles (32), Wearing Apparels (33)
Leather Industries and Footwear	11	Leather Industries (34), Footwear (35)
Printing, Paper Product, furniture and Other Wood Product	12	Sawmills (36), Other Wood Products (40), Paper Products and Furniture (41), Printing (43)
Wood Products	13	Plywood and Particle Board (37), Builders' Carpentry and Joinery (38), Wooden and Cane Containers (39)
Publishing, Paints and Varnishes	14	Publishing (42), Paints and Varnishes (47)
Petroleum Refinery	15	Petroleum Refinery (44)
Basic Chemicals, Fertilizers and Tyres	16	Basic Chemicals (45), Fertilizers (46), Tyres (51)
Plastic and Other Chemical product	17	Pharmaceuticals, Medicinal Chemicals & Botanical Product (48), Soap, Perfumes, Cleaning & Toilet Preparations (49), Other Chemicals Product (50), Plastics Products (55)
Manufacture of Rubber Products	18	Rubber Processing (52), Rubber Gloves (53), Rubber Products (54)
Glass Product, Clay and Ceramic	19	Sheet Glass and Glass Products (56), Clay and Ceramic (57)
Cement Manufacture ,Concrete & Other Non Metallic Mineral Products	20	Cement, Lime and Plaster (58), Concrete & Other Non-Metallic Mineral Products (59)
Manufacture of Metal Product	21	Iron and Steel Products (60), Basic Precious and Non-Ferrous Metals (61), Casting of Metals (62), Structural Metal Products (63), Other Fabricated Metal Products (64)
Manufacture of Machinery/Equipments	22	Industrial Machinery (65), Special Purpose Machinery (67), Electrical Machinery and Apparatus (70), TV, Radio Receivers & Transmitters & Associated Goods (75), Motorcycles (81), Other Transport Equipment (83), Other Manufacturing (84)
Other Manufacturing	23	General Purpose Machinery (66), Domestic Appliances (68), Office, Accounting & Computing Machinery (69), Other Electrical Machinery (71), Insulated Wires & Cables (72) , Electrical Lamps & Lighting Equipment (73), Semi-Conductor Devices, Tubes and Circuit Boards (74), Medical, Surgical & Orthopedic Appliances (76), Measuring, Checking & Indust. Process Equipt (77), Optical Instruments and Photographic Equipment (78), Watches and Clocks (79), Motor Vehicles (80), Ships and Boats Building, Bicycles & Invalid Carriages (82), Recycling (85)
Electricity & Gas	24	Electricity & Gas (86)
Waterworks	25	Waterworks (87)
Construction	26	Residential (88), Non - Residential (89), Civil Engineering (90)
Special Trade Works	27	Special Trade Works (91)
Wholesale, Retail Trade, Hotel and Restaurants	28	Wholesale and Retail Trade (92), Accommodation (93), Restaurants (94)
Transport	29	Land Transport (95), Water Transport (96), Air Transport (97), Other Transport Services (98)
Port and Airport Operation Services	30	Port and Airport Operation Services (99)

Other Transport and Communication	31	Highway, Bridge & Tunnel Operation Services (100), Communication (101)
Banks and Housing	32	Banks (102), Ownership Dwellings (107)
Other Finance and Housing	33	Financial Institution (103), Insurance (104), Other Financial Institution (105), Real Estate (106)
Other Business and Private Services	34	Rental and Leasing (108), Research and Development (110), Professional (111), Private Non - Profit Institution (118), Amusement and Recreational Services (119), Other Private Services (120)
Business, Private and Government Services	35	Computer Services (109), Business Services (112), Public Administration (113), Education (114), Health (115), Defence and Public Order (116), Other Public Administration (117).

Source: Authors' own aggregation based on the Malaysian 2005 Input-Output table.

Table A-2: Average Prices, CO_2 Emission Factor and Adjusted Unit for Different Kind of Fuels

Type of fuel	Average price RM (unit)	CO_2 Emission Factor	Source	Adjusted unit for density at 30^0 C
Manufacture of Charcoal	91 (tone)*	2361(kg/tonne)	S.C. Bhattacharya et al,.(2002)	-
Crude oil	57.15 (barrel **)	431.7(kg/barrel)	From Appendix H of the instructions to Form EIA-1605	-
Natural Gas	25.55 (SCF)#	55555.56 (kg/SCF)	ICBE	-
Kerosene	1941 (tonne)^	2.55 (kg/Liter)	ICBE	1 tonne = 1273 liter
Liquefied Petroleum Gas	1649 (tonne)^	1.59 (kg/Liter)	ICBE	1 tonne = 1835 liter
Fuel Oil (distillate)	1389 (tonne)^	2.66 (kg/Liter)	www.epa.gov/appdstar/pdf/brochure.pdf	1 tonne = 1051 liter
Diesel	1814 (tonne)^	2.73 (kg/Liter)	ICBE	1 tonne = 1159 liter
ATF&AV GAS	1814 (tonne)^	2.18 (kg/Liter)	www.epa.gov/appdstar/pdf/brochure.pdf	1 tonne = 1412 liter
Gasoline (Motor Spirits)	1857 (tonne)^	2.31(kg/Liter)	ICBE	1 tonne = 1356 liter
Processing of nuclear fuel	-	0	Zarina Ab Muis[1]	-
Production, collection and distribution of electricity	0.23 (Kwh)^	0.61(kg/Kwh)	CCIC	-
Steam and hot water supply	-	0		-
Collection, purification and distribution of water	-	0		-

*ITC calculations based on COMTRADE statistics (USD is converted to RM)
** PETRONAS
# Calculated from data given by DOS and EIA
^ Calculated from data given by DOS and oil industry conversions
[1] DOS

Table A-3: Relevant elasticities with rounded values of $E_{ij}^{v} > 0.001$ as filter

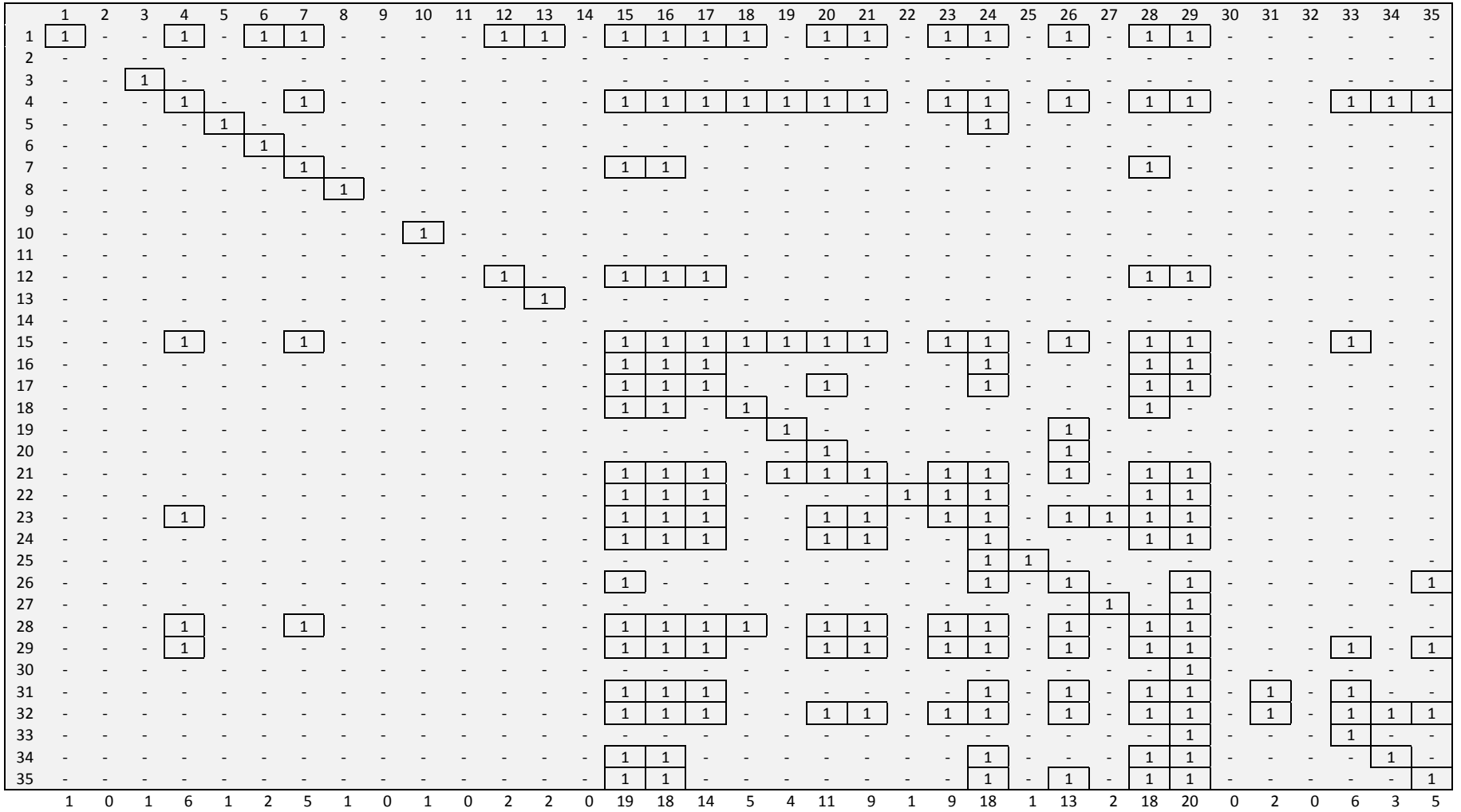

Table A-4: Summary of Results

Sector Codes	Key Sectors: Primary and Secondary	CO_2 in tonnes	Distributive Effect	Total Effect	Dominant Effect; T = Total Effect, D = Distributive Effect	User Sectors that indirectly produce CO_2 emissions	Supply Sectors that directly produce CO_2 emissions
4	Mining	7,115,815	0.1714**	0.0661**	**D**	4, 7, 15-21, 23, 24, 26, 28, 29, 33-35	1, 4, 15, 23, 28, 29
15	Petroleum refinery	16,172,261	0.1063**	0.1501**	**T**	4, 7, 15-21, 23, 24, 26, 28, 29, 33	1, 4, 7, 12, 15-18, 21-24, 28, 29, 31, 32, 34, 35
16	Basic Chemicals, fertilizers and tyres	10,833,884	0.0613**	0.1006**	**T**	15-17, 24, 28, 29	1, 4, 7, 12, 15-18, 21-24, 28, 29, 31, 32, 34, 35
17	Plastic and Other Chemical product	7,265,085	0.0545**	0.0674**	**T**	15-17, 20, 24, 28, 29	1, 4, 12, 15, 21, 23-24, 28, 29, 32
21	Manufacture of Metal Product	4,236,733	0.0418**	0.0393**	**-**	15, 16, 17, 19-21, 23, 24, 26, 28, 29	1, 4, 15, 21, 23, 24, 28, 29, 32
23	Other Manufacturing	3,605,095	0.0456**	0.0335**	**-**	4, 15-17, 20, 21, 23, 24, 26-29	1, 4, 15, 21-23, 28, 29, 32
24	Electricity & Gas	12,556,950	0.0742**	0.1166**	**T**	15-17, 20, 21, 24, 28, 29	1, 4, 5, 15-17, 21-26, 28, 29, 31, 32, 34, 35
28	Wholesale, Retail Trade, Hotels and Restaurants	4,492,370	0.0371**	0.0417**	**T**	4, 7, 15-18, 20, 21, 23, 24, 26, 28, 29	1, 4, 7, 12, 15-18, 21-24, 28, 29, 31-32, 34-35
29	Transport	17,657,886	0.1037**	0.1639**	**T**	4, 15-17, 20, 21, 23, 24, 26, 28, 29, 33, 35	1, 4, 12, 15-18, 21-24, 26-35
1	Agriculture	891,288	0.0435*	0.0083	**D**	1, 4, 6, 7, 12, 13, 15-18, 20, 21, 23, 24, 26, 28, 29	1
26	Construction	3,123,907	0.0235	0.029*	**T**	15, 24, 26, 29	1, 4, 15, 19-21, 23, 26, 28, 29, 31, 32, 35
32	Banks and Housing	14	0.0357*	0	**D**	15-17, 20, 21, 23, 24, 26, 28, 29, 31, 33-35	
	Total	**87,951,288**	**0.7986**	**0.8165**			
	Other Sectors (non key)	**19,761,791**	**0.2014**	**0.1832**			

**** Primary key sectors**

***** Relevant given scaled elasticity over 100**