Structural Change and Lifestyle Effects on Industrial Air Emissions

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Abstract

Emission rates are changing mainly as a result of the change in economic structure, in particular change in the production structure. The changes in the production structure are determined primarily by the level of domestic and external demands. Among others, change in household lifestyles is expected to contribute significantly to the production growth and consequently may have importance impact on emission rates. Therefore, this paper attempts to measure the effect of structural changes on industrial emissions during the 1991-2000 period. Our results clearly show that the source of emission growth is largely determined by the growth in the emission and exports. The study however, could not measure the lifestyle effect, given the limitation on sectoral air emission and lacking of household expenditure survey for year 1991.

Keywords: Structural change, input-output, air emissions, structural decomposition analysis

1. Introduction

The way we all live our lives in the developed world produces tones of emissions – the four main sources of emissions from a household– food, houses, cars and holidays. Practically every aspect of modern life in the developed world is damaging the environment, but people are generally so shielded from that damage that it's easy to ignore or not aware of it. At the moment humans are making carbon dioxide faster than plants can turn it back into oxygen. Carbon dioxide goes into the atmosphere and forms a blanket over the earth and warming it up. Low carbon lifestyles create less carbon dioxide emissions. Household activities and consumption that create carbon dioxide are driving cars, heating homes, generating electricity, flying planes, making goods in factories and transporting things a long way. The reported level of CO_2 emissions in

Malaysia produced by a 24 million population in the year 2000 was 144,528, with CO_2 emissions per capita of 0.63%. (www.eek.co.uk/index)

Malaysian economy has undergone rapid growth and changes in the industrial structure since the 1980s. As the industrialization process matured, the share of the manufacturing sector become saturated while that of the service sector as whole contributed to a larger portion of gross economic activity. A study of Malaysia sources of growth using srtructural decomposition analysis (SDA) by Rohana (2006) from the period of 1991 to 2000 revealed that the output growth dominated by the effects of domestic demand expansion, which contributed about 48 percent and followed by export demand expansion 50 percent. Based on the study done by Chang and Lin (1998) using the structural decomposition of industrial CO_2 emissions, the result indicate that primary factor that increase of emissions is the level of domestic final demand and exports. CO_2 emissions are always associated with the final demand (directly or indirectly) for goods and services. This paper extends the application of SDA to examine the emissions trends and effects of various sources of change in household behavioural patterns in the private consumption.

The rest of this paper is organised as follows: Section 2 discusses the technical details of our decomposition analysis which extends to incorporate emission variable into the model. Section 3 briefly explains the sources of data associated in this study. Section 4 presents the result of the decomposition analysis of emission growth. Finally, Section 5 summarizes some important conclusions derived from the study.

2. Methodology

Input-output model analyses the inter-industry relations in an economy, showing the interdependencies among industries in supplying input and consuming output among the production activities. Specifically, the independencies among industries within the input-output model can be shown based on the following material balance equation;

$$\mathbf{X}_i = \sum x_{ij} + c_i + g_i + s_i + k_i + e_i \qquad (1)$$

where x_{ij} denotes output from sector i demanded as intermediate consumption to sector j, c_i is private consumption, g_i is government consumption, s_i is change in stock, k_i is gross fixed capital formation and e_i is export. In the input-output model, equation (1) can be transformed into the matrix notation as;

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1} (\mathbf{c} + \mathbf{g} + \mathbf{s} + \mathbf{k} + \mathbf{e}) \qquad (2)$$

where $\mathbf{I}$ is the identity matrix and $(\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse matrix. Each of the elements of Leontief inverse matrix shows total requirements, both the direct and indirect effects of increasing final demand for any sector. Further denoting $\mathbf{R}$ as the Leontief inverse matrix, $(\mathbf{I} - \mathbf{A})^{-1}$ and $\mathbf{f}$ as the final demand vector, $(\mathbf{c} + \mathbf{g} + \mathbf{s} + \mathbf{k} + \mathbf{e})$, equation (2) can be simplified as;

$$\mathbf{X} = \mathbf{R}\mathrm{f} \qquad (3)$$

The input-output framework has been extended by many researchers to account for environmental pollution generation associated with the inter-industry activity (see for instance, Roca and Serrano, 2007; Lenzen et al, 2003; Sung-In, 2000). The most common procedure is to assume that emissions are linearly related to gross output of each sector, in a way that each industry generates residuals in fixed proportions with respect to the production output. The emission coefficient of pollutant **h** (in our study **h** is represented by air emission) by sector *j* can be obtained simply by dividing the total emission **m** of a sector *j* by the total output **X**

$$\mathbf{h} = \mathbf{m}/\mathbf{X} \tag{4}$$

Given this assumption, it is possible to obtain the total emission caused by the *f*-category of final demand through the use of emission coefficients for each sector, that is,

$$\mathbf{H} = \mathbf{h}.\mathbf{X} = \mathbf{h}.\mathbf{R}.\mathbf{f} \tag{5}$$

To measure how the structural changes have affected the industrial air emissions during the period 1991-00, a structural decomposition analysis (SDA) can be applied (see for instance, Chang and Lin, 1998; Munksgaard et al, 2000; Kim, 2002). By comparing the two input-output tables for Malaysia for 1991 and 2000, the effects of the underlying causes for the changes in industrial air emissions can be measured simultaneously by the SDA. It is a common descriptive tool in explaining the changes in some variables into the changes in its determinants. Typically, the SDA is used to determine the changes (growth) in sectoral output by separating the causes into several individual factors which mainly involving changes (growth) in the technologies, domestic demands and exports. Specifically, the decomposition of output growth over a period can be calculated as the first difference of equation (3)

$$\Delta\mathbf{X} = \mathbf{X}_1 - \mathbf{X}_2 \tag{4}$$
$$\Delta\mathbf{X} = \mathbf{R}_1\mathbf{f}_1 - \mathbf{R}_0\mathbf{f}_0 \tag{5}$$
$$= \mathbf{R}_0(\mathbf{f}_1 - \mathbf{f}_0) + (\mathbf{R}_1 - \mathbf{R}_0)\mathbf{f}_1 = \mathbf{R}_0(\Delta\mathbf{f}) + (\Delta\mathbf{R})\mathbf{f}_1 \tag{6}$$

or similarly

$$= \mathbf{R}_1(\mathbf{f}_1 - \mathbf{f}_0) + (\mathbf{R}_1 - \mathbf{R}_0)\mathbf{f}_0 = \mathbf{R}_1(\Delta\mathbf{f}) + (\Delta\mathbf{R})\mathbf{f}_0 \tag{7}$$

The issue of non-uniqueness of structural decomposition forms has received considerable attention because the numerical results can be varied subject to the index number problem. Alternatively, Dietzenbacher and Los (1998) have shown the average of polar decompositions, which can be viewed as the extension of the Laspeyres and Paasche form when more than two determinants exist, which is a very good approximation of the average of all the potential decompositions that exist (Liu and Saal, 2001). Hence,

$$\Delta\mathbf{X} = 1/2(\mathbf{R}_0 + \mathbf{R}_1)(\Delta\mathbf{f}) + 1/2(\Delta\mathbf{R})(\mathbf{f}_0 + \mathbf{f}_1) \tag{8}$$

The change in the Leontief inverse $\mathbf{R}$, in terms of the change in the input coefficient of matrix $\mathbf{A}$, can be derived as follows;

$\Delta\mathbf{R} = \mathbf{R}_1 - \mathbf{R}_0 = \mathbf{R}_1[(\mathbf{I} - \mathbf{A}_0) - (\mathbf{I} - \mathbf{A}_1)]\mathbf{R}_0 = \mathbf{R}_1(\mathbf{A}_0 - \mathbf{A}_1)\mathbf{R}_0$. Similarly, $\Delta\mathbf{R} = \mathbf{R}_0(\mathbf{A}_1 - \mathbf{A}_0)\mathbf{R}_1$. Therefore,

$$\Delta\mathbf{R} = \mathbf{R}_1(\Delta\mathbf{A})\mathbf{R}_0 = \mathbf{R}_0(\Delta\mathbf{A})\mathbf{R}_1 \qquad (9)$$

Substituting equation (9) into the second term of equation (8), we obtain the following expression

$$1/2(\Delta\mathbf{R})(\mathbf{f}_0 + \mathbf{f}_1) = 1/2\,[\mathbf{R}_1(\Delta\mathbf{A})\mathbf{R}_0\mathbf{f}_0 + \mathbf{R}_0(\Delta\mathbf{A})\mathbf{R}_1\mathbf{f}_1] = 1/2\,[\mathbf{R}_1(\Delta\mathbf{A})\mathbf{x}_0 + \mathbf{R}_0(\Delta\mathbf{A})\mathbf{x}_1] \qquad (10)$$

Combining all elements in equation (10) and (8), we achieve the complete decomposition forms of sectoral output growth

$$\begin{aligned}
\Delta\mathbf{X} = {} & 1/2\,[\mathbf{R}_1(\Delta\mathbf{A})\mathbf{x}_0 + \mathbf{R}_0(\Delta\mathbf{A})\mathbf{x}_1] + && (11a)\\
& 1/2(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{c}) + && (11b)\\
& 1/2(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{g}) + && (11c)\\
& 1/2(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{s}) + && (11d)\\
& 1/2(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{k}) + && (11e)\\
& 1/2(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{e}) + && (11f)
\end{aligned}$$

According to equation (11), the sectoral outputs can be decomposed into the effects determined by; (11a) changes in input coefficient or technology, (11b) the effect of consumption expansion, (11c) the effect of government consumption expansion, (11d) the effect of change in stock expansion, (11e) the effect of gross fixed capital formation expansion and (11f) the effect of export expansion.

The above framework in addition, can be extended to incorporate the change in air emissions as a result of change in its determinants. Using $\Delta\mathbf{H} = 1/2(\Delta\mathbf{h})(\mathbf{X}_0 + \mathbf{X}_1) + 1/2(\mathbf{h}_0 + \mathbf{h}_1)(\Delta\mathbf{X})$ in connection with the expressions in (11) for $\Delta\mathbf{X}$ yields

$$\begin{aligned}
\Delta\mathbf{H} = {} & 1/2(\Delta\mathbf{h})(\mathbf{X}_0 + \mathbf{X}_1) + && (12a)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)[\mathbf{R}_1(\Delta\mathbf{A})\mathbf{x}_0 + \mathbf{R}_0(\Delta\mathbf{A})\mathbf{X}_1] + && (12b)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{c}) + && (12c)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{g}) + && (12d)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{s}) + && (12e)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{k}) + && (12f)\\
& 1/4(\mathbf{h}_0 + \mathbf{h}_1)(\mathbf{R}_0 + \mathbf{R}_1)\,(\Delta\mathbf{e}) + && (12g)
\end{aligned}$$

The interpretation of the last five expressions remains the same, while (12a) indicates the effects of the changes in the sectoral air emission per unit of output.

3. Data Sources

The source of air emissions growth are analysed on the basis of input-output for 1991 and 2000, which was published by Department of Statistics (DOS), Malaysia. The original input-output industries however, have been aggregated into 11 industries, given the limitation of the emissions data. In order to reveal the real changes in the variables, the 1991 input-output table has to be expressed in 2000 constant prices, making all the matrices comparable. To deflate the input-output table, we use the available price indices, i.e. the producer price indices (PPI), consumer price indices (CPI), import price indices (IPI) and implicit price deflator (IPD) for value added. All of the price indices are supplied by the DOS.

Given the availability of the sectoral IPD, we therefore prefer to apply the RAS technique for deflation inter-industry transactions as suggested by Dietzenbacher and Hoen (1998) instead of using double-deflation technique. Specifically, the PPI are used mainly for deflating the sectoral output and component of final demands. The IPI are applied to deflate the competitive import. Sectoral value added is altered by using the available IPD. To some extent, commodities are altered by using the same price indices because the available of PPI, IPI and IPD only at aggregate form. The total intermediate demand and intermediate input are simply obtained by taking residual between total output (input) and primary input (value added and import) and final demand. Therefore, the inter-industry transactions are altered based on bi-proportional matrix adjustment, given the known total intermediate demand and intermediate input.

Data on air emissions are scarce at industry level and in some cases they are not available. Therefore, in this study we only focus on ten selected industrial sectors which have air emission figures. All the data are estimated based on emission load from major fuel burning equipment by industrial sectors, collected by the Department of Environment (DOE), Malaysia. The total emission load is measured in metric tonnes and may comprise several types of emissions such COx, SOx, NOx, HC and particulate. Nevertheless, given the limitation of data at disaggregate level, we totally depend on the aggregate air emission.

4. Result and discussion

In discussing the results, we first focus on the general changes in sectoral air emission that had been occurred during the period of study. Next, we further discuss intensively the causes for the changes which can be measured into several individual growth effects.

Table 1 shows some dramatic changes in the sectoral emission share over the period 1991-00. The trend generally reveals a reduction of sectoral air emissions which the iron and steel industry contributes the highest air emission reduction by 7.33%. This is followed by electrical (4.59%), paper and printing (4.08%), textile (3.76%) oil palm estates (3.52%), wood based (2.63%), mining (0.16%) and metal fabric (0.03). While almost industries experienced negative growth in emission loads, the rubber product and food industries tend to show a positive growth in emission. It can be verified that the highest growth in emission is contributed by the rubber product (20.98%) and followed by food (5.12 %).

TABLE 1

Table 1 above only shows a general changes in the sectoral air emission. In this respect, the analysis based on sources of output changes conducted below may give more clear indication on the fundamental problems related to the structural transformation and emission.

A decomposition of emission growth into its cause components for the period 1970-00 is presented in Table 2. Focusing first on overall decomposition effects, we can observe that the prominent feature is that the changes in the air emission explain for all the changes. Specifically, the change in emissions contributed the most to the growth in sectoral output (71.75%), followed by change in export (24.97 %) and change in consumption (3.36 %). The effect from change in technical coefficient, government consumption, and change in inventory on the other hand show a negative growth on the emission. Therefore, the overall results indicate that the source air emission growth during the period 1991-2000 was largely determined by growth of air emissions. Looking at individual industries, the highest and positive effect from the source of emission come from rubber product (81.33%), food (71.68 %), oil palm estates (69.84%), textiles (68.61%) and wood based (64.64%).

The effect of changes in export is the second most factors that determine the growth in sectoral emission, registered by 24.97%. All the sectors revealed a positive emission due to change in export, with metal fabric show the highest change (188.90 %), electrical (104.97%), paper and printing (80.42%) respectively. The rapid economic growth and transformation from being agrarian-based to industrial-based orientation is expected to contribute largely to the export of these products which in turn generate a large emission. In fact, the expansion of the industrial sector was strongly accompanied by outward policy oriented, that is, export-led growth.

Interestingly, change in private consumption contributes only 3.36% to the growth in emission. It can be seen that consumption in the paper and printing products generate largely impact to the change in emission by 51.19%. Consumption on food products in addition, generates less than the rate of emission produced by mining and textile products. The results nevertheless should not interpret as strong evidence from the impact of private consumption, given the limitation of data coverage. As previously mentioned, data on air emissions scarce at industry level and to some extent they are not available. Consequently, this study only covers ten selected industries, based on availability of the data at hand.

Another important features reveal in Table 2 is change in technical coefficient generates negative effect to the emission growth. Almost all industries and particularly the mining industry experienced a negative effect from the change in technical coefficient. This may reflect to the fact that a change in technology (e.g. energy efficiency technique) has generated significant impact in reducing the rate of air emission. Technological changes in the metal fabric, electrical, oil palm estate and textile oil palm estates industries on the other hand, contribute the positive effect to the growth in air emission.

5. Conclusion

The study shows that different sectors may have different effect in change in emissions. These differences are primarily due to differences in the type of economic activities and the linkages among the sectors. Our analysis reveals that the changes of output growth of most sectors are largely correlated with change in emissions and export. Therefore, the government should simultaneously emphasize environmental and export policies that will induce more environmentally conscious industries. If global control of air emissions is to occur in future, such measures should be initially aim largely at identifying the industrial activities that contributed to the pollution.

Results derived from this study nevertheless should not be interpreted as strong evidence due to data limitation. Data on air emission that used in this study only cover for the ten selected industries. Similarly, the effect from the change in household lifestyle could not be distinguished from the private consumption due to the fact that household expenditure survey for year 1991 and previous is not available. Consequently, the results may not reflect the real emission problem in the economy and complete emission data at disaggregate industry levels is necessary for policy formulation.

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Table 1: Sectoral air emission and change in share, 1991-00

Sectors	1991 (metric tones)	2000 (metric tones)	Change in share (%)
Oil palm estates	1,602.60	6,219,745.94	-3.52
Mining	12.60	0.35	-0.16
Textile	642.00	1,623,542.03	-3.76
Food	840.20	5,837,018.23	5.12
Wood Based	2,903.80	12,654,072.25	-2.63
Paper and Printing	321.00	0.06	-4.08
Rubber Product	612.00	10,626,369.71	20.98
Metal Fabric	2.40	1.08	-0.03
Iron and Steel	577.40	1.26	-7.33
Electrical	361.60	1.02	-4.59

Table 2: Structural decomposition source of emission growth, 1991-00

Sectors	Δ Emission		Δ Technical coefficient		Δ Private consumption		Δ Export		Δ Gross fixed capital formation		Δ Government consumption		Δ Inventory	
	Metric tonnes	%	Metric tonnes	%	Metric tonnes	%	Metric tonnes	%	Metric tonnes	%	Metric tonnes	%	Metric tonnes	%
Oil palm estates	4,488,223.12	69.84	136,339.74	2.12	441,062.27	6.86	1,420,809.25	22.11	83,475.54	1.30	10,537.85	0.16	-154,400.20	-2.40
Mining	-18.53	-162.72	-2.51	-22.04	1.53	13.41	7.62	66.88	0.34	2.96	0.41	3.61	-0.24	-2.10
Textile	1,138,640.25	68.61	17,803.24	1.07	213,585.08	12.87	302,447.21	18.22	-463.17	-0.03	1,292.14	0.08	-13,771.70	-0.83
Food	4,390,894.76	71.68	-39,600.36	-0.65	694,554.93	11.34	1,023,464.15	16.71	32,403.77	0.53	33,831.87	0.55	-10,127.12	-0.17
Wood Based	8,400,237.72	64.64	-23,048.85	-0.18	67,337.41	0.52	4,286,155.70	32.98	27,844.51	0.21	28,891.10	0.22	208,282.37	1.60
Paper and Printing	-937.54	-255.39	-2.92	-0.80	187.91	51.19	295.21	80.42	64.09	17.46	10.22	2.78	15.94	4.34
Rubber Product	9,383,223.95	81.33	-161,473.41	-1.40	-115,993.52	-1.01	2,638,991.50	22.87	23,505.49	0.20	-123,530.81	-1.07	-107,709.79	-0.93
Metal Fabric	-5.57	-322.82	0.16	9.39	0.18	10.49	3.26	188.90	-0.10	-5.76	0.06	3.51	0.28	16.28
Iron and Steel	-1,076.50	-173.83	-40.59	-6.55	56.27	9.09	476.75	76.98	10.75	1.74	15.42	2.49	-61.39	-9.91
Electrical	-924.67	-215.88	28.94	6.76	17.63	4.12	449.63	104.97	-7.13	-1.66	4.93	1.15	2.35	0.55
Total	27,798,256.9	71.75	-69,996.56	-0.18	1,300,809.69	3.36	9,673,100.27	24.97	166,834.08	0.43	-48,946.82	-0.13	-77,769.49	-0.20

Source: computed from the model