Decomposition effects of carbon dioxide emission from industrial sectors in Japan and South Korea: what are the potentials for emission abatement?

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DECOMPOSITION EFFECTS OF CARBON DIOXIDE EMISSION FROM INDUSTRIAL SECTORS IN JAPAN AND SOUTH KOREA: WHAT ARE THE POTENTIALS FOR EMISSION ABATEMENT?

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ABSTRACT: *Japan and South Korea heavily depend on energy consumption to develop their economy. This has consequently led to considerable growth in their industrial CO_2 emission in the past few decades. Although the upward trend of CO_2 emissions in South Korea is more pronounced than that of Japan. This study empirically investigates the decomposition effects of industrial CO_2 emissions as well as the emission abatement potentials in these countries' industrial sub-sectors. Log Mean Divisia index method I (LMDI I) was adopted in decomposing aggregate industrial CO_2emission into four distinct effects - fuel share, energy intensity, structural change, and industrial activity. Industrial fuel mix is discovered to be the prime cause of growing industrial CO_2 emission in these two OECD countries. This study was carried out in twelve key energy consuming industrial sub-sectors spanning over the period of 1990 to 2009, thereby providing broad intuitions into industrial CO_2 emissions patterns and easy identification of abatement potentials in Japan and South Korea industries. The CO_2 abatement potentials are identified in petrochemicals, machinery equipment, iron and steel and non-metallic minerals industries of Japan as well as textile and leather, mining and quarrying, non-ferrous metals, machinery equipment and wood and wood product industries of South Korea. In conclusion, the study recommends that policy measures of these two Asian countries should be directed at adopting energy saving technologies and promoting the industrial use of cleaner as well as renewable energies.*

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ABBREVIATIONS

Btu	-	British thermal unit
CI	-	Carbon dioxide Intensity
CIA	-	Central Intelligence Agency
CO_2	-	Carbon dioxide
EI	-	Energy Intensity
ESDS	-	Economic and Social Data Service
GDP	-	Gross Domestic Product
GHG	-	Greenhouse gas
GW	-	Giga Watt
IEA	-	International Energy Authority
LMDI	-	Logarithmic Mean Divisia Index
Mb/d	-	Million barrels per day
Mt	-	Million tonnes
NO_2	-	Nitrous Oxide
OECD	-	Organisation for Economic Cooperation and Development
PPP	-	Purchasing Power Parity
SO_2	-	Sulphur dioxide
STAN	-	Structural Analysis

LISTS OF FIGURES

1. INTRODUCTION

The industrial sector plays a significant role in the process of economic development and equally constitutes one of the largest energy-consuming sectors in any economy (Ritu, et al 2006 and Sudhakara and Binay, 2010). This sector in Japan and South Korea is poised for transformation due to the nations' impressive economic growth as well as growing global concern for climate change stimulated by greenhouse gases (GHGs), particularly carbon dioxide (CO_2) emissions due to increasing use of fossil fuels[1].

The purpose of this study is to investigate the trends and drivers of energy-related CO_2 emissions in the industrial sectors in Japan and South Korea as well as emission abatement potentials available for both countries in respect of their rising industrial carbon dioxide emissions.

To achieve these objectives, this study has employed the Logarithmic Mean Divisia Index (LMDI I) introduced by Ang and Liu (2001) to conduct decomposition analysis on the energy-related CO_2 emissions from Japan's and South Korea's industrial sectors during the period from 1990 to 2010. It focuses on variations in four key factors contributing to the industrial sectors' CO_2 emission namely: fuel share, energy intensity, structural change (or relative sectoral activity) and economic growth. Furthermore, decomposition analysis – has been used to investigate the possible abatement potentials in the industrial CO_2 emissions in Japan and South Korea over the specified period of time.

This study provides useful information to policy makers, analysts as well as governments of the concerned countries on the available emission abatement potentials and the need for setting standards for curbing their industrial energy-related CO_2 emissions. It also unravels the urgent need for these economies to internalise greener manufacturing mode, improve energy efficiency and upgrade their industrial emission standards.

The rest of the paper is structured as follows. Section 2 provides an overview of the economies concerned and concise literature review on decomposition methodologies. In section 3, the decomposition technique introduced by Ang and Liu (2001) is presented. Section 4 gives detailed interpretation of the findings while Section 5 concludes the study.

[1]See detailed evidence in Chapter 2

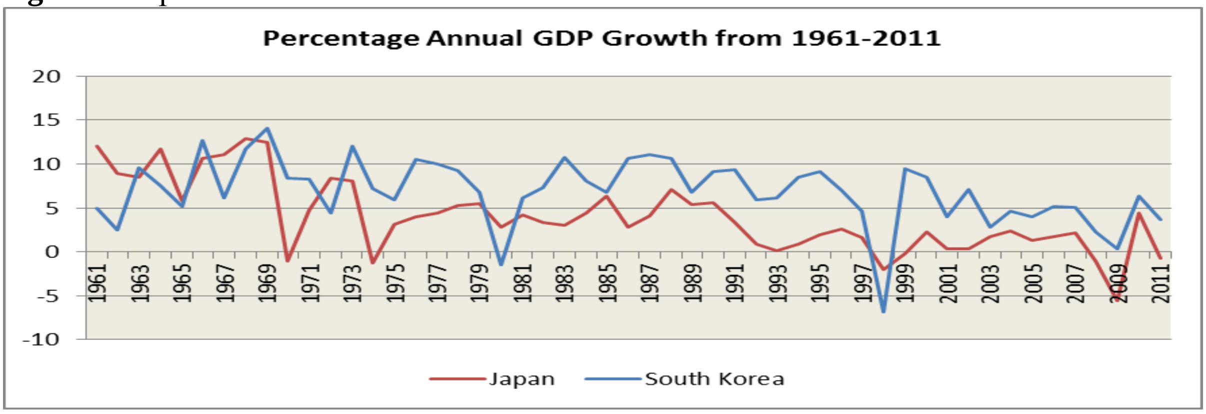
2. OVERVIEW OF THE ECONOMY, ENERGY AND LITERATURE

2.1 Synopsis of Japan and South Korea's Economy

Japan is the World's tenth most populous country with an estimated population of 127.8 million people and Gross Domestic Product (GDP) of $5.06 trillion (constant 2000 US$) in 2011 (World bank Development Indicator (WDI), 2012). As one of the world's leading industrialized and technologically advanced economies, Japan operates high-tech based economy supported by its thriving industrial sector which greatly relies on foreign raw materials and energy sources (Central Intelligence Agency (CIA), 2012).The country's economic growth averaged 4 per cent and 1.7 per cent in the 1980s and 1990s respectively. However, the GDP growth declined sharply by roughly 5.5 per cent in 2008 due to economic recession but recovered within the next two years and stood at 4.4 per cent in 2010[2]. In 2011, Japan's recuperating economic growth was hammered back to -0.7 per cent by the disastrous tsunami of March 2011- gigantic 9.0 magnitude earthquake (CIA, 2012). In spite of this, World Bank's GDP ranking of 2012 positions the country as the third largest economy in terms of GDP Purchasing Power parity.

On the other hand, South Korea is a developed East Asian nation that has displayed an incredulous economic performance over the last four decades and now a globally recognized (high-tech) industrialized economy (CIA, 2012). In year 2004 precisely, South Korea joined the World's league of trillion dollar economies, and is currently the world's twelfth largest economy with estimated GDP per capita (at constant 2000 US$) of $16.68 thousand in 2011(WDI, 2012).

Figure 1: Japan and South Korea's GDP Growth from 1961 in 2011



Source: Author's Computation from World Bank Development Indicator 2012

[2] Author's estimation from World bank Indicator 2012 as presented in Figure 1

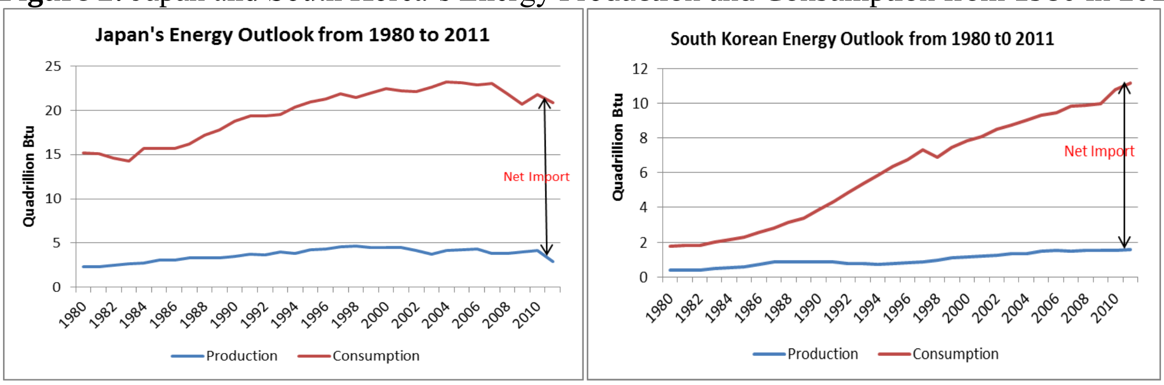
Although the Asian financial crisis of 1997-98 strongly affected South Korea's GDP growth pattern (as evident in Figure 1), GDP growth dropped by 6.9 per cent in 1998, and then recuperated, growing by 9 per cent in the subsequent fiscal year 1999-2000. As an export intensive economy, South Korea was severely affected by the 2008 global economic downturn, but speedily recovered in successive years, and recorded 6.3 per cent growth in 2010.

2.2 Energy Outlook: Production versus Consumption

Since 2009, Japan has been the world's fourth largest energy consuming country after the United States, China, and Russia (IEA, 2012). Owing to its rising energy consumption, limited fossil fuel reserves and static local production, the nation increasingly depends on imports to meet its energy demand. IEA Statistics of 2012 ranks Japan as the world's first, second and third largest net importer of Liquefied Natural Gas (LNG), coal and crude oil respectively, Bulk of Japan's crude oil imports come from the Middle East, with Saudi Arabia and United Arab Emirate topping the list. In summary, the nation produces and consumes 2.95 and 20.82 quadrillion Btu equivalent of energy respectively in 2011 leaving a wide net import gap of about 17.87 quadrillion Btu as depicted in Figure 2 below.

In a similar vein, South Korea has very limited domestic energy resources and as a result imports almost all its fossil energy needs. It is currently the world's second largest importer of liquefied natural gas, and one of the biggest importers of oil as well as coal IEA, (2012). In 2011, South Korea's total energy production stood at 1.56 quadrillion Btu while consumption was 11.16 quadrillion Btu. This reveals a wide net import margin estimated to exceed 85 per cent in 2011[3].

Figure 2: Japan and South Korea's Energy Production and Consumption from 1980 in 2011

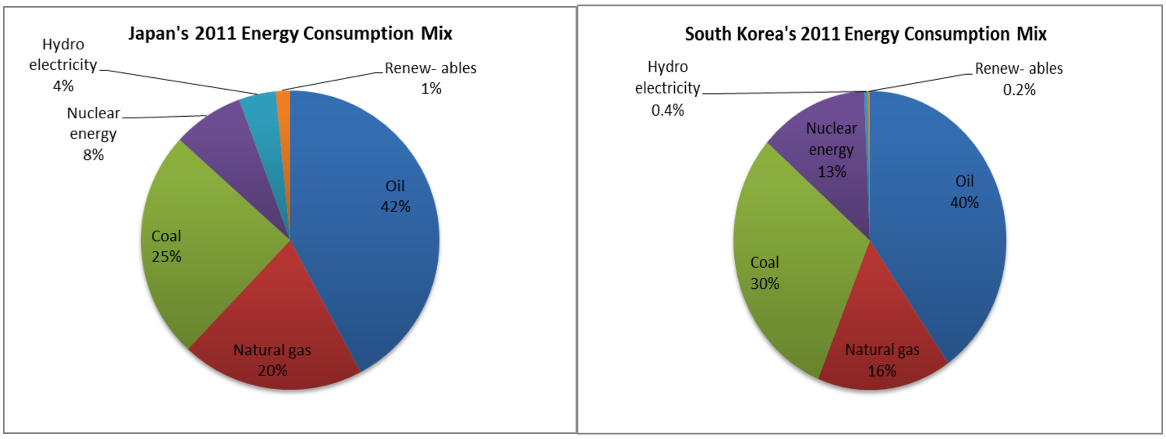


Source: Author's Computation from IEA Statistics of 2012

[3] As presented in Fig. 2

On the energy composition basis, oil dominates Japan's energy mix and accounts for 42 per cent, coal 25 per cent, natural gas 20 per cent, nuclear 8 per cent while hydro and other renewables supply the remaining 5 per cent. Similarly, South Korea's energy Mix is equally dominated by oil (40 per cent), followed by coal (30 per cent), then natural gas and nuclear which contribute 16 and 13 per cent respectively. However, the role of hydro and other renewables is of negligible interest (which is just 1 per cent)[4].

Figure 3: Japan and South Korea's Energy Consumption Mix for 2011



Source: Author's Computation from IEA Statistics of 2012

In sum, fossil fuels strongly dominate the energy portfolio of these countries (contributing 87 per cent in Japan and 86 per cent in South Korea) which consequently make these economies highly susceptible to climatic and environmental challenges including air pollution, acid rain, water pollution from the discharge of sewage and industrial effluents.

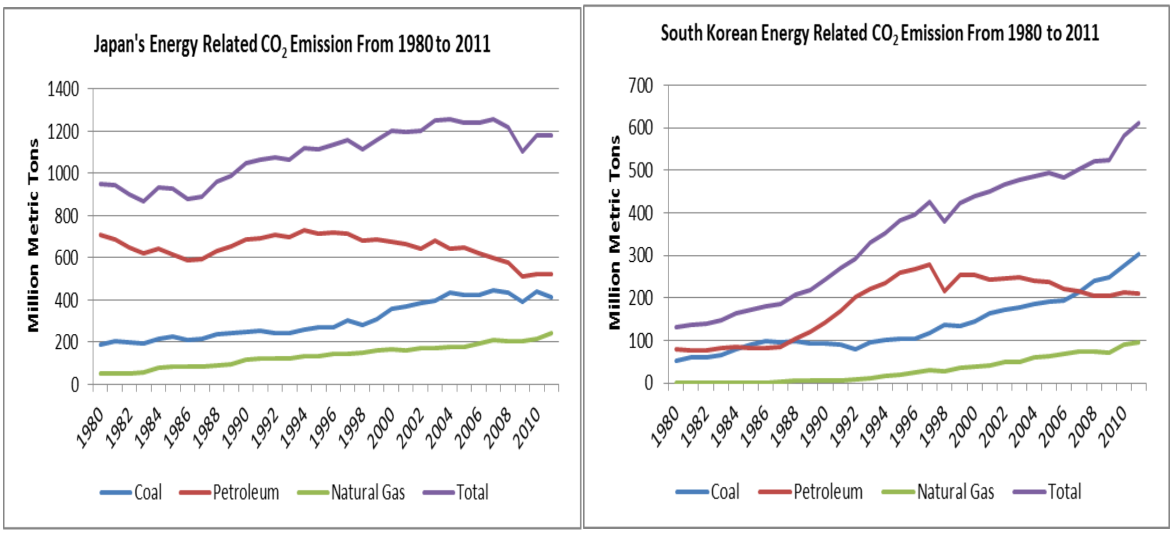
2.3 Energy Related CO_2 emission trends

Total energy- induced CO_2 emissions of Japan was estimated to be 1180.6 million tons (MT) in 2011, an increase of 6.8 per cent over the 2009 level of 1104.9 MT which makes the per capita emissions to be 9.2 tons in 2011. Of the total emission, petroleum products account for 523.2 MT, which is 44.3 per cent while coal and natural gas account for another 35 and 20.7 per cent of emissions respectively[5]. This substantial emission discharge positions Japan as the fifth largest emitter in the world.

[4] Estimated from IEA, 2012 statistics and presented in Fig. 3
[5] As illustrated in Fig. 4

Turning to South Korea, as much as 610.95 MT of CO2 emissions takes place in the economy in 2011. By way of fuel, coal, being the dirtiest of fossil fuels currently constitutes half of total emission i.e. 303.2 MT in 2011followed by petroleum products and natural gas which respectively contribute 211.6 and 96.1 MT.

Figure 4: Japan and South Korea's Energy Related CO_2 Emissions from 1980 to 2011



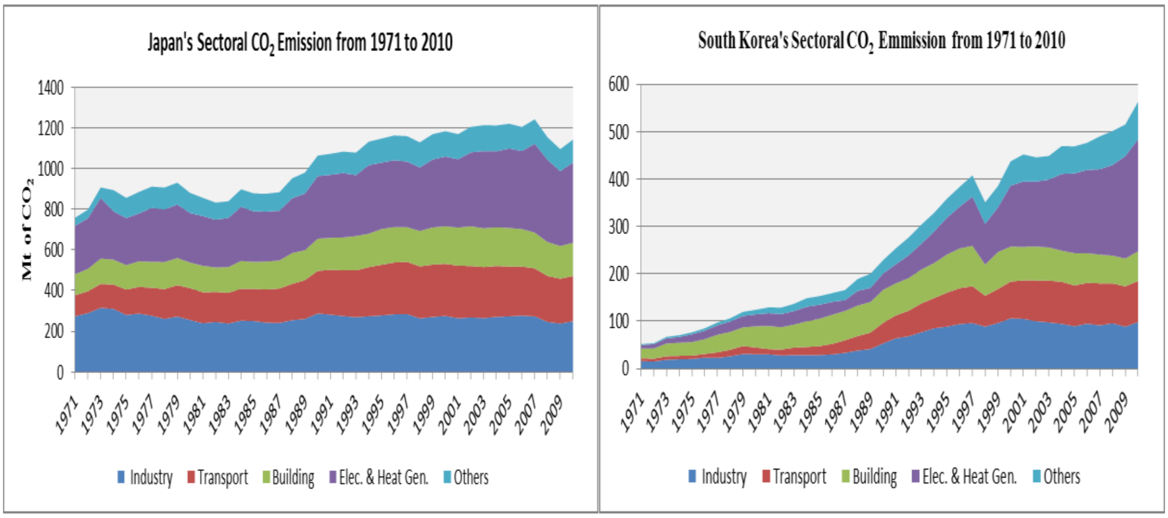
Source: Author's Computation from IEA Statistics of 2012

Thus, carbon dioxide emission in Japan and Korea predominantly originates from heavy utilization of fossil fuels in the economy, which is directed towards meeting both intermediate as well as final demand use at various levels of production of goods and services.

At the Sectoral level, industry constitutes the key sector behind the rising CO_2 emissions trends in these two countries - which accounts for roughly 22 and 18 per cent in Japan and South Korea respectively[6], increase is majorly due to the surge in the energy consumption of the industrial sector, which is linked to the high growth in electricity consumption and generation.

[6]*See* Fig. 5

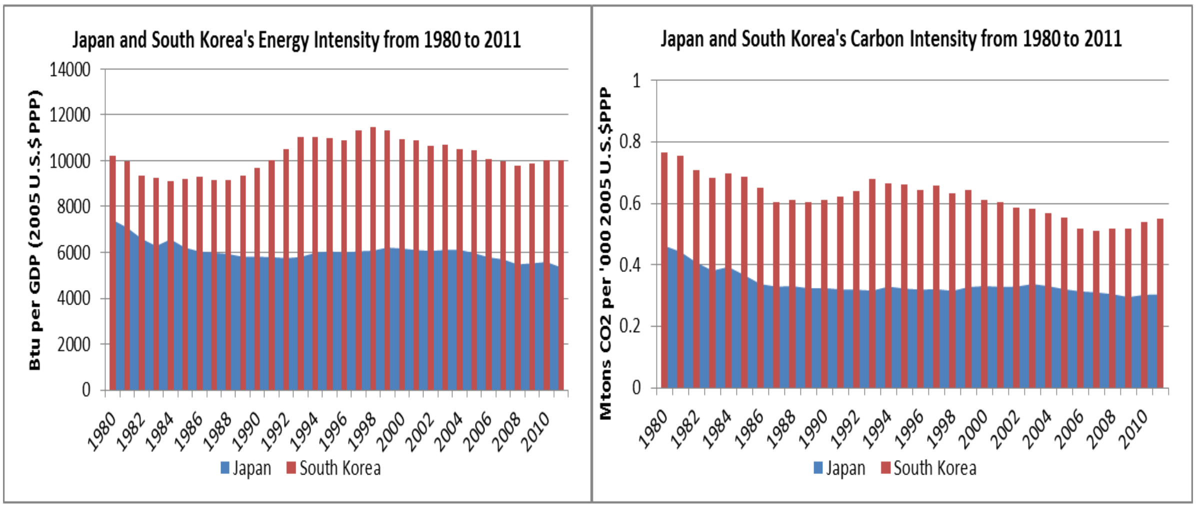
Figure 5: Japan and South Korea's Energy Related CO_2 Emissions from 1980 to 2011



Source: Author's Computation from IEA Statistics of 2012

To provide a detailed comparison of energy intensities in Japan and South Korea, Figure 6 presents International Energy Agency (IEA) intensities estimates for both countries.

Figure 6: Japan and South Korea's Energy and CO_2 Intensities from 1980 to 2011



Source: Author's Computation from IEA Statistics of 2012

Figure 6 shows that energy intensity in South Korea is higher than that in Japan. Also, in terms of CO_2 intensity, which shows the level of CO_2 emissions from energy use per unit of output, South Korea is significantly ahead of Japan.

2.4 Literature Overview on decomposition studies

Being one of the most widely adopted methodologies in analysing energy demand, energy intensity and energy-related gas emissions, index decomposition analysis (IDA) has been the focus of a significant volume of literature.

Howarth et al. (1991) employed Laspeyres and Divisia indexes to decompose energy consumption in the manufacturing sectors of eight OECD countries from 1973 to 1987 and then compared the strengths and weaknesses of these two methods. Their finding reveals a slight difference the Laspeyres and Divisia index methods.

Similarly, Lynn et al. (1996) used these indicators to examine the impacts of transport activities, travel modes, energy intensity, CO_2 intensity and transportation fuel mix on the increasing CO_2 emission in nine OECD countries, and found out that travel-related activities were the major cause of CO_2 emission upsurge.

Lin and Chang (1996) also used the Divisia index method to determine the emission proportions of CO_2, NO_2 and SO_2 emanating from Taiwan’s key economic sectors starting from 1980 to 1992. Their work postulates that economic growth had concrete impact on the changes in emission intensities over the studied period, although the effect of fuel mix was proclaimed to be minimal.

Moreso, the Divisia decomposition technique was adopted by Shrestha and Timilsina (1996) to access the effects of fuel quality, fuel mix and production efficiency of thermal generating plants on CO_2 intensity in twelve selected Asian nations between 1980 and 1990. Ten OECD countries were the study scope of Greening et al. (1999), where they applied the adaptive weighted Divisia index to analyse freight sectors’ energy consumption and carbon intensity. They found that growing total energy consumption and carbon intensity are primarily driven by increase in activity, which is discovered to be paralleled to GDP growth.

On Italy, Mazzarino (2000) applied the Divisia decomposition to ascertain the prime factors influencing CO_2 emission from the transport sector in the country between the period of 1980 and 1995. This was achieved by decomposing CO_2 emission into five key components: fuel mix, modal structure, economic growth (GDP), energy intensity and transportation intensity.

The result identified economic growth as the principal driver of the increasing CO_2 emission in Italy's transportation sector.

Li and Lee (2001) creatively decomposed Taiwan's petrochemical industries into eight factors using an integrative approach (by combining structural change effect, input–output modelling and integrative index decomposition).Whereas Gonzalez and Suarez (2003) decomposed variations in Spain's electric energy intensity and discovered a considerable decrease in intensity which was eventually attributed to structural and energy intensity effects.

In a similar vein, Steenhof (2006) adopted the Laspeyres index to decompose industrial sector electricity demand into three components viz: structural share, industrial activity and energy intensity. He asserted that industrial activity and fuel shift were the main propellers of China's increasing electricity demand.

Ang and Lee (1994) performed empirical as well as comparative analysis of five decomposition methodologies and successfully established that fact that simple average Divisia and adaptive weighting index approaches yield smaller residuals in decomposition amidst other methods.

In their relentless effort towards ensuring perfect decomposition, effective handling of zero values in the dataset and feasible decomposition of differential change, Ang et al., 1998 introduced a refined Divisia index method, the logarithmic mean Divisia index (LMDI) approach. The work of Ang and Liu (2001) later presented a new decomposition method called log-mean Divisia method I (LMDI I), with the desired features of perfect decomposition as well as aggregation consistency.

Having compared the decomposition methodologies, Ang (2004) pointed out multiplicative and additive logarithmic mean Divisia index approach as the best methods with strong theoretical foundation, flexible adaptability, ease of operation and result interpretation. Ang (2005) further provided a practical guide on general formulation of the logarithmic mean Divisia index (LMDI) and then used industrial energy consumption and CO_2 emissions as appropriate examples for perfect understanding of the applications and strengths of the LMDI approach.

Among the recent studies, Lu et al. (2007), used a simple average Divisia index Approach for Taiwan, Germany, Japan and South Korea to examine the effects of five factors (comprising emission coefficient, vehicle fuel intensity, the number of vehicles, population and GDP) on CO_2 emissions from high way transportation.

Ilyoung el al. (2010) employed the Log Mean Divisia index method to decompose setoral energy-related CO_2 emissions in South Korea over a15-year period (1990-2005).Their study examined seven sub-sectors in terms of key effects including fuel mix, energy intensity, structural change and economic growth. The results revealed that Economic Growth was the major explanation for the increasing sectoral CO_2 emissions in Korea's economy.

Although several studies have used decomposition analysis to examine energy-induced CO_2 emissions at sectoral, national and cross-regional levels, limited research has identified abatement potentials either in the industrial sector or in the road transport sectors. This paper attempts to fill this gap in the context of Japan and South Korea.

3. METHODOLOGY

This study adopts the new decomposition method called the Logarithmic Mean Divisia Index I (LMDI I) introduced by Ang and Liu (2001). This method gives perfect decomposition and also allows for consistency in aggregation. With these key properties, the technique is superior to several earlier proposed decomposition methods. The LMDI technique relied upon the pivotal proposition of the Divisia index by French Economist; Francois Divisia (1925), in a paper written in French. The form of the LMDI utilized in this study (i.e. LMDI I) is a variant of LMDI II form used by Ang and Choi (1997). Although both forms possess the advantage of not leaving residual after decomposition however LMDI I has unique advantage over LMDI II as the former is more consistent in aggregation.

3.1 LMDI Approach to Decomposition Analysis[7]

Logarithmic Mean Divisia Index decomposes CO_2 emission into the output effect, intensity effect, fuel share effect, structural change effect and emission factor effect (Ki-Hong and Ang, 2003). Presented below is the concise summary of LMDI technique's formulae adapted from Ang and Liu (2001)

[7] *See* Ki-Hong & Ang, 2003, Ang, 2005 and Zhang, 2013

Let C be the aggregate industrial CO_2 emission, let q be the factor and n be the number of factors affecting CO_2 emission. Thus,

$$C = \sum_i^n q_{1,i}\, , q_{2,i}, \ldots q_{n,i} \tag{1}$$

$$C_i = q_1, q_2, \ldots q_n \tag{2}$$

Where sub-script i depicts the attribute of aggregate such as industrial CO_2 emitting sub-sectors, fuel used, etc.

To account for changes in industrial energy-related CO_2 emission between two periods, denoted as Δ**C**, then total change in overall industrial emission is can be written as:

$$\Delta\boldsymbol{C} = \boldsymbol{C^T} - \boldsymbol{C^O} = \sum_i^n q^T{}_{1,i}\, , q^T_{2,i}, \ldots q^T_{n,i} - \sum_i^n q^0_{1,i}\, , q^0_{2,i}, \ldots q^0_{n,i} \tag{3}$$

Where C^T represents Industrial CO_2 emission in year t, and C^O represents industrial CO_2 emission in the reference base year.

Further, since overall industrial CO_2 emission emanates from four main sources, energy intensity, sectoral activity, economic growth and fuel share. Change in the total industrial CO_2 emission is equal to the addition of the change in these four factors. Applying the additive form of LMDI decomposition, ΔC can then be re-written as:

$$\Delta\boldsymbol{C} = \boldsymbol{C^T} - \boldsymbol{C^O} = \Delta\boldsymbol{C}_{q1} + \Delta\boldsymbol{C}_{q2} + \Delta\boldsymbol{C}_{q3} + \Delta\boldsymbol{C}_{q4} \tag{4}$$

Where q_1, q_2, q_3 and q_4 denote energy intensity, sectoral activity, economic growth and fuel share respectively. To this end, change in industrial energy-related CO_2 emission can be decomposed into the change in these factors in the respective sub sectors.

In line with the Log Mean Divisia Index, each of the components of total industrial CO_2 emission is then computed as:

$$\Delta q_1 = \sum_i^{12} L(C_i^T, C_i^0)\ \ln(q^T_{1,i}/q^0_{1,i}) \tag{5}$$

$$\Delta q_2 = \sum_i^{12} L(C_i^T, C_i^0)\ \ln(q^T_{2,i}/q^0_{2,i}) \tag{6}$$

$$\Delta q_3 = \sum_i^{12} L(C_i^T, C_i^0)\ \ln(q^T_{3,i}/q^0_{3,i}) \tag{7}$$

$$\Delta q_4 = \sum_i^{12} L(C_i^T, C_i^0)\ \ln(q^T_{4,i}/q^0_{4,i}) \tag{8}$$

In the above expressions, i represents the sub-sectors. There are twelve sub-sectors in this study[8], superscript T denotes the value of variable denotes in year T, superscript o expresses the same variable at the initial period or base year while other variables remain as earlier defined.

3.2 Sources of Data

Data used in this study covers 1990-2009. 2010 was excluded due to data unavailability. Energy consumption data are extracted from International Energy Administration through ESDS. Annual value added data for the industrial sub-sectors as well as data on value added deflators are obtained from OECD's Structural Analysis (STAN) Database, while emission factors are sourced from EUROSTAT.

4. RESULTS[9] AND DISCUSSION

Since overall industrial energy-induced CO_2 emission has been decomposed on four-year basis, which now makes it possible to determine the contributions of each sub-sector to the overall industrial emission over time and easily identify the abatement potentials. Therefore, this section presents the results of this time series decomposition analysis has aggregated into five periods, beginning from 1990 to 2009, but the last period does not count up to four years because data for 2010 are not yet available.

4.1 Industrial Emission Growth Rate Versus Abatement Potentials

The Figure 7 and 8 depict the disaggregated industrial CO_2 emission growth patterns in Japan and South Korea respectively during the last two decades. In Japan, The highest growth in Industrial CO_2 emission was recorded from 1994-98 and least for the period of 2006-09; however the average growth rate of the Industrial CO_2 emission for the entire period is estimated at 1.2 per cent. The examination of the Japan's industrial sub-sectors' CO_2 emission growth reveals that petrochemicals, machinery and iron industries recorded the highest growth in CO_2 emission during the first two periods, although the growth started declining in the following two periods but grew again in the last period by roughly 30 per cent, 24 per cent and 18 per cent respectively compared to the previous period. On the contrary, the emission rate of mining, transport equipment and non-ferrous metals industries

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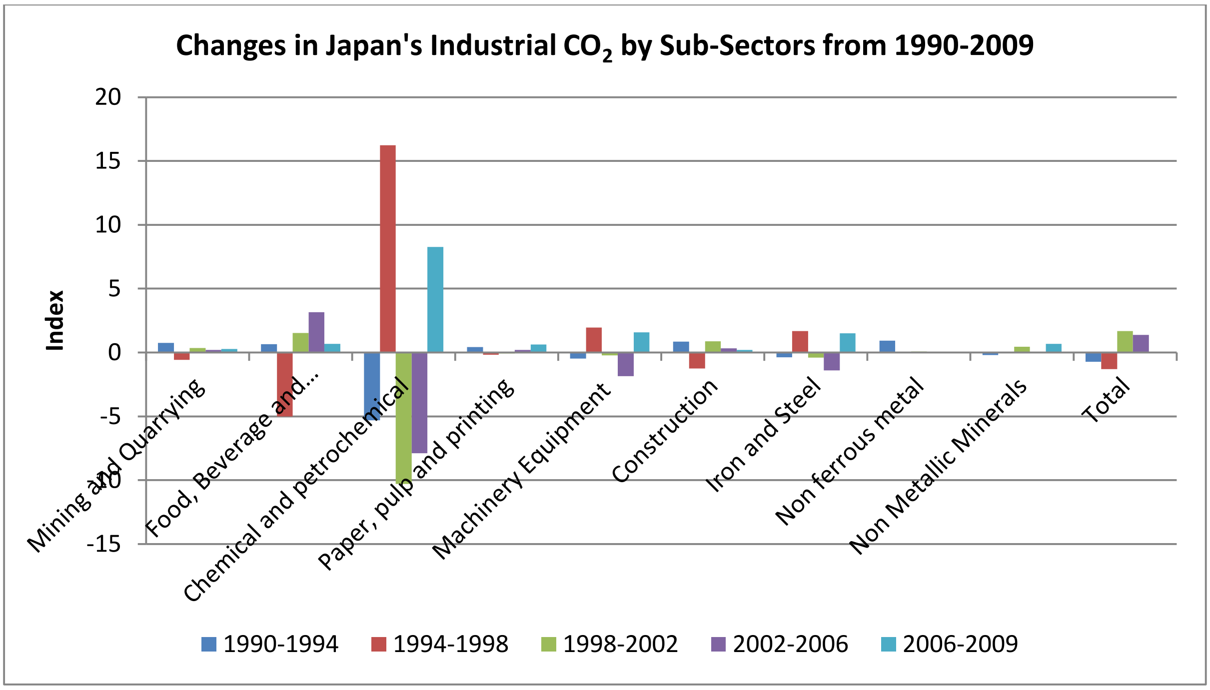
[8] *See* the sub-sectors consider in Figure 7 and 8 respectively
[9] *See* detailed decomposition results in the appendix

has been declining over the periods. Food and beverage industries emission has been fluctuating in the first four periods but declined by 16 per cent in the last period.

It is clear that during the period 1990-09, total industrial CO_2 emission from Japan's industrial sub-sectors has shown a slightly descending trend. Nevertheless, the contribution of industries (like chemical and petrochemicals, machinery, iron and steel and non-metallic mineral industries)[10] to the total industrial CO_2 emissions in the country is still relatively significant and requires considerable abatement measures.

Figure 7: Decomposed Growth Pattern of CO_2 Emission by Japan Industries from 1990-2009



Source: Author's Computation from LMDI Decomposition Analysis

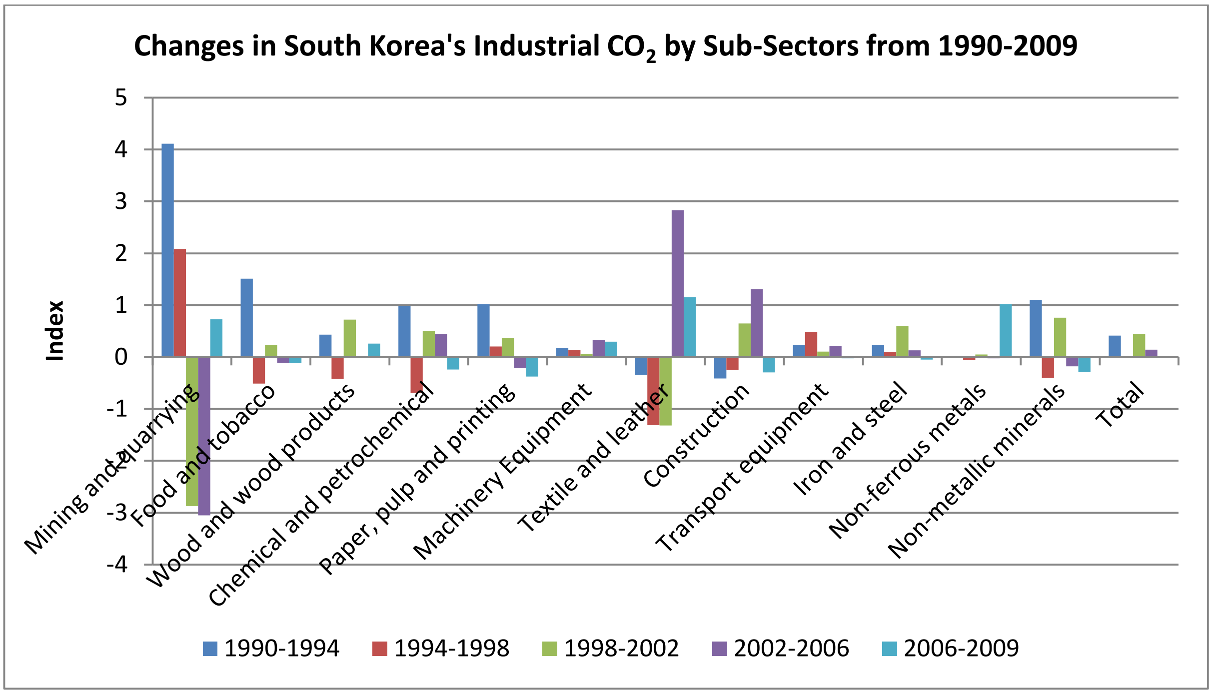
Similarly, Figure 8 below provides CO_2 emission growth patterns among various industrial sub-sectors in South Korea during the study periods. The overall growth rate of industrial CO_2 emission in South Korea has been rising and falling over the periods but averaged at 2.4 per cent for the entire period. The peak and the least emission growth rates are recorded in the periods 1998-2002 and 2006-2009 respectively.

It is noticed that the sub-sectoral level that the growth in CO_2 emitted by food and beverages, petrochemicals, paper and pulp, construction as well as iron and steel industries has

[10]As evident in Fig. 7

decreased noticeably during the periods investigated. On the contrary, the emission rate of machinery, non-ferrous metals and non-metallic mineral industries has increased while that of mining, wood and textile industries has been fluctuating over time[11].

Figure 8: Decomposed Growth Pattern of CO_2 Emission by South Korea's Industries from 1990-2009



Source: Author's Computation from LMDI Decomposition Analysis

This implies that despite the intermittent emission trend in South Korea's industrial emission during these periods, there was a significant reduction in emission discharged among food and tobacco, chemicals, paper and pulp, construction and iron and steel industries while the other industries in the economy emit considerable amount CO_2 which therefore requires appropriate emission curbing efforts.

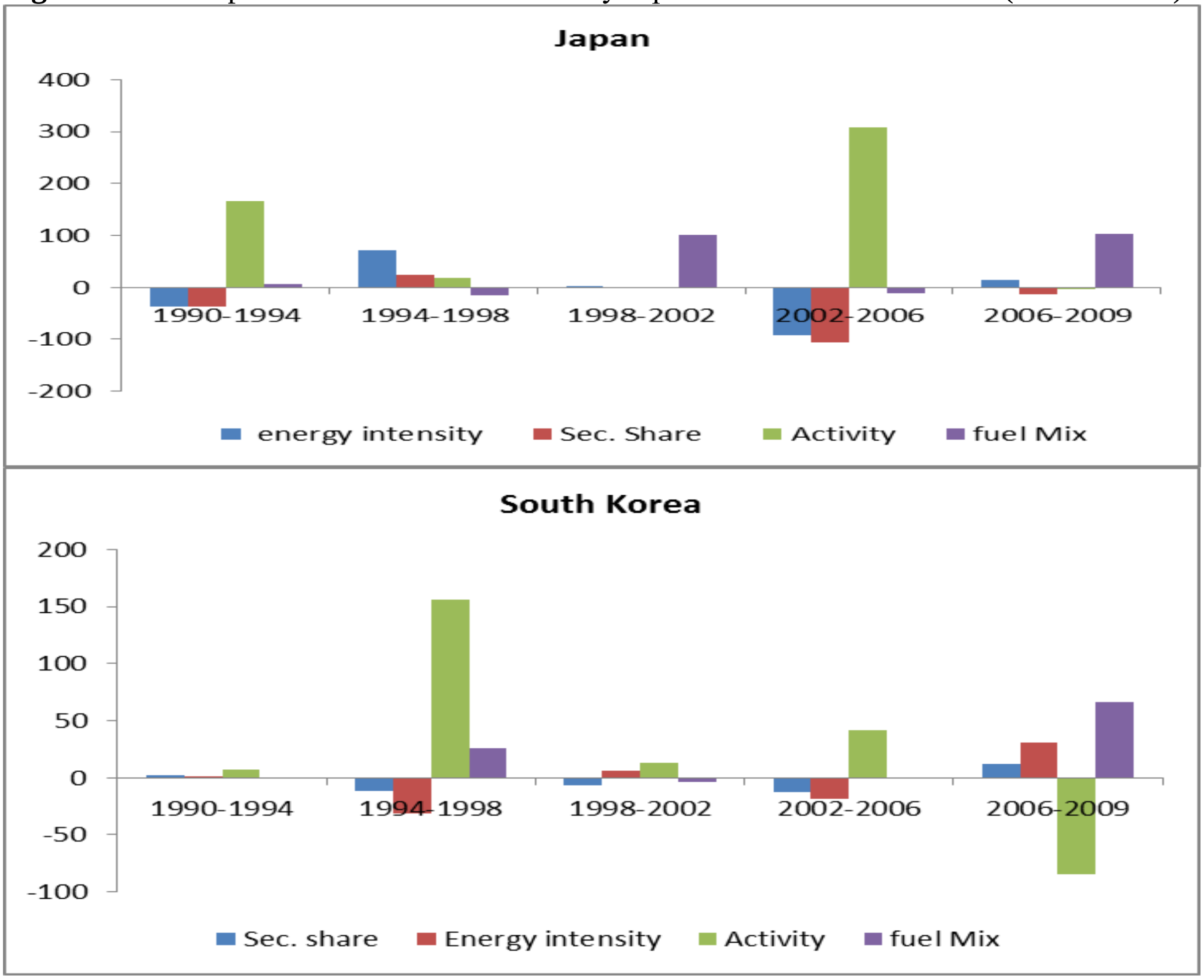
4.2 Decomposition Effects

The positive or negative contribution of each of the four factors – energy Intensity (change in technologies), sectoral share (change in product mix), fuel mix (composition of fuel use) and industrial activity (output level per industry) to the total industrial CO_2 emissions is presented below. Figure 9 shows the aggregate of each component (either positive or negative) in each period while figure 10illustrates their overall net effect over the study period. It should be noted that negative values implies net reduction in industrial CO_2 emission. For better cross-

[11] Comprehensive illustration in Figure 8 and Tables in the appendix

sectoral appraisal of the effect, magnitude and sign, the two countries are presented separately.

Figure 9: Decomposed CO_2 Emission Effect by Japan and Korea's Industries (1990 – 2009)

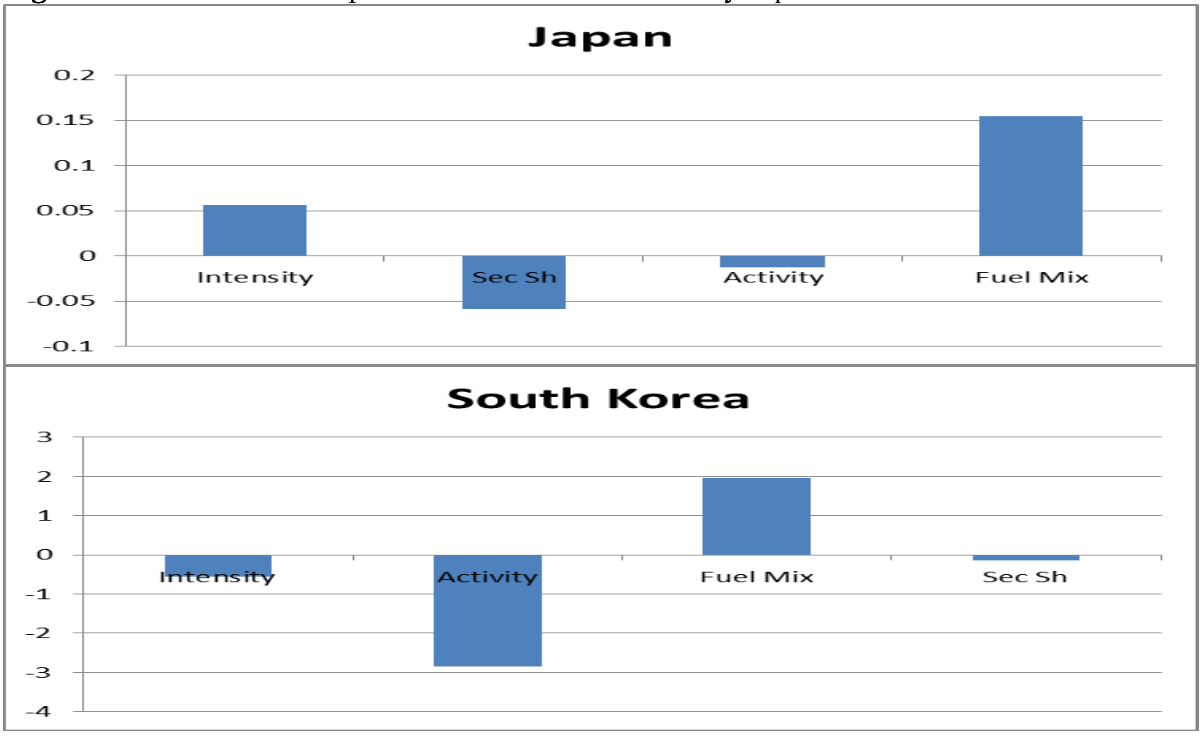


Source: Author's Computation from LMDI Decomposition Analysis

In Japan, industrial activity solely constitutes over 80 per cent of total industrial CO_2in the periods 1990-1994 and 2002-2006; the intensity effect, structural change effect and activity effect jointly contributed to the increase in industrial CO_2 emission during 1994-1998; while fuel mix accounts for substantial emission contribution between 1998-2002 and 2006-2009. The contribution of structural effects and intensity has declined over the time. This implies; an overall decrease in emission emanating from structural effect, a considerable contribution by intensity and structural effect while inter-fuel substitution is responsible for the bulk of industrial CO_2 emission during the examined period (1990–2009).

In a similar vein, Industrial activity is the major component explaining the observed increase in South Korea industrial CO2 emissions in the first three periods (1990-2002). The positive impact of output effect is very apparent during the second period (1994-1998) but declined drastically in the period 2006-2009 - when it has a negative impact. During the last period 2006-2009, the fuel mix effect becomes the most important contributor which accounts for about 54 per cent of Korea's total industrial CO_2 emission. This was followed by energy intensity effect which increased overall emission by for period 2006-2009 by 32.3 per cent while the structural effect only increased in the same period by 14.7, as clearly shown in Figure 9 above.

Figure 10: Overall Decomposed CO_2 Emission Effect by Japan and Korea's Industries



Source: Author's Computation from LMDI Decomposition Analysis

In sum, the depiction in Figure 10 affirms that, among the four factors, fuel mix is by far the most important factor contributing to the rising industrial CO_2 emissions in Japan and South Korea during the examined period. This reflects the dominance of carbon-intensive fuels in the countries industrial energy portfolio.

5. CONCLUSION

The aim of this study is to identify the abatement potentials available via decomposition of factors that have influenced changes in the quantity of industrial CO_2 emitted from the Japan and South Korea's industrial sectors. By adopting Logarithmic Mean Divisia Index Method (LMDI I - a decomposition method introduced by Ang and Liu in 2001), the industrial energy use and the associated CO_2 emission during the period 1990 to 2009 are investigated under four distinctive factors: fuel share, energy intensity, structural change (or activity in the sector) and industrial activity. The results reveal that the perceived variation in Japan and South Korea's industrial CO_2 emissions is majorly due to the increasing dominance of carbon-stimulating fuels in countries' industrial fuel mix but the effect is more pronounced in South Korea. This is mainly because of the increasing share of electricity-utilization in the industrial sectors of these two economies and their growing dependence on fossil fuels for electricity generation. Also, energy intensity partially propelled Japan's industrial CO_2 emission while the other two components; industrial activity and structural change stimulate downward industrial CO_2 emission during the period examined.

The CO_2 abatement potentials are identified in key energy-intensive industrial sectors including (petrochemicals, machinery equipment, iron and steel and non-metallic minerals industries) in Japan as well as (textile and leather, mining and quarrying, non-ferrous metals, machinery equipment and wood and wood product industries are identified) in South Korea. It is concluded that to effectively address the Industrial CO_2 abatement potentials identified in the long term, policy measures should be directed at adopting energy saving technologies and promoting the industrial use of cleaner as well as renewable energies.

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APPENDIX

Result of decomposition analysis of CO_2 emissions from Japan sub-sectors						
Sectors	Period	Factors				
		Intensity	Sec Sh	Activity	Fuel Mix	Aggregate
Mining and Quarrying	1990-1994	0.28	28.63	78.84	303.66	74.64
	1994-1998	41.44	4.94	20.44	666.00	-57.87
	1998-2002	-38.35	-16.07	99.03	-422.12	35.29
	2002-2006	12.06	29.22	-337.84	-217.36	20.49
	2006-2009	84.57	53.28	239.53	-230.19	27.46
Food, Beverage and Tobacco Manufacturing	1990-1994	-398.06	-4792.42	73.69	78.94	64.62
	1994-1998	762.16	-1094.53	16.80	-9.48	-501.18
	1998-2002	-132.39	-1119.73	81.59	30.75	153.15
	2002-2006	-395.23	9941.56	-293.65	-6.32	316.32
	2006-2009	263.52	-2834.88	221.56	6.11	67.09
Chemical and petrochemical	1990-1994	-73.38	646.70	72.84	54.89	-529.71
	1994-1998	-169.55	32.81	14.93	-34.23	1622.15
	1998-2002	232.06	-115.15	66.88	34.56	-1029.12
	2002-2006	26.64	-739.88	-273.95	-0.56	-789.37
	2006-2009	84.23	275.52	219.29	45.33	826.05
Paper, pulp and printing	1990-1994	13.78	17.82	82.03	-16.17	42.99
	1994-1998	21.94	9.30	17.16	1127.49	-17.33
	1998-2002	89.73	28.92	80.11	-275.08	-8.10
	2002-2006	-7.19	59.93	-308.05	-869.26	19.32
	2006-2009	-18.26	-15.98	228.75	133.03	63.11
Machinery Equipment	1990-1994	-4.46	2.00	73.30	118.75	-46.84
	1994-1998	54.09	33.67	14.84	7.24	196.47
	1998-2002	0.05	8.56	61.90	-2.66	-22.99
	2002-2006	46.18	53.33	-268.20	-5.92	-184.95
	2006-2009	4.14	2.43	218.16	-17.41	158.32
Construction	1990-1994	-25.61	10.43	71.96	86.99	84.17
	1994-1998	139.00	31.58	15.86	-63.61	-125.04
	1998-2002	-22.97	17.87	75.24	13.97	88.92
	2002-2006	1.71	55.31	-258.17	44.09	31.47
	2006-2009	7.87	-15.19	195.11	18.56	20.48
Iron and Steel	1990-1994	23.24	8.97	74.85	90.30	-36.65
	1994-1998	-1.60	19.55	15.02	-49.07	167.85
	1998-2002	5.98	-5.65	64.97	-15.98	-40.90
	2002-2006	4.10	12.13	-272.19	68.39	-140.99
	2006-2009	68.28	65.00	217.35	6.35	150.69
Non ferrous metal	1990-1994	38.58	179.74	51.45	87.68	93.36
	1994-1998	128.23	-178.37	9.52	13.10	0.00
	1998-2002	-50.60	69.22	41.76	-10.55	8.72
	2002-2006	5.36	-2.09	-15.90	-8.02	-2.14
	2006-2009	-21.57	31.51	13.17	17.78	0.06
Non Metallic Minerals	1990-1994	-3.11	-0.65	5.25	-0.02	-0.18
	1994-1998	2.30	1.13	1.05	0.01	0.05
	1998-2002	8.82	9.32	34.57	59.62	59.81
	2002-2006	-1.26	1.85	-18.15	0.00	0.00
	2006-2009	93.25	88.35	77.28	40.40	40.31

Result of decomposition analysis of CO2 emissions from South Korea's sub-sectors						
Sectors	Period	Intensity	Sec Sh	Activity	Fuel Mix	Aggregate
Mining and Quarrying	1990-1994	1881.91	23.38	23.98	32.63	411.29
	1994-1998	87.78	20.75	7.75	67.39	208.25
	1998-2002	-889.99	19.48	27.99	-16.77	-287.41
	2002-2006	-1067.78	21.71	28.05	6.21	-305.17
	2006-2009	88.08	14.68	12.22	10.55	73.04
Food, Beverage and Tobacco Manufacturing	1990-1994	-42.40	14.32	21.62	14.10	151.16
	1994-1998	47.58	12.93	9.52	-52.75	-51.37
	1998-2002	55.78	24.16	32.07	169.73	23.06
	2002-2006	14.65	38.82	26.44	-80.16	-11.36
	2006-2009	24.40	9.76	10.36	49.08	-11.49
Wood & wood products	1990-1994	79.90	17.21	17.88	12.48	43.09
	1994-1998	97.62	21.32	3.88	189.07	-41.67
	1998-2002	-254.82	-32.51	33.26	-153.44	71.92
	2002-2006	19.50	32.29	31.51	114.77	0.55
	2006-2009	157.80	61.69	13.46	-62.88	26.11
Chemical and petrochemical	1990-1994	-3.81	323.94	20.27	0.85	98.40
	1994-1998	91.42	303.69	8.69	-30.59	-69.21
	1998-2002	-10.69	-62.35	29.82	114.11	50.54
	2002-2006	4.59	-293.92	29.12	-11.51	44.20
	2006-2009	18.49	-171.37	12.10	27.14	-23.92
Paper, pulp and printing	1990-1994	8.02	-40.07	17.59	4.44	101.67
	1994-1998	-11.55	13.57	9.12	14.45	20.51
	1998-2002	40.96	30.15	34.36	25.78	36.98
	2002-2006	9.29	82.73	28.38	33.03	-21.78
	2006-2009	53.28	13.62	10.55	22.30	-37.38
Machinery Equipment	1990-1994	7.73	8.77	15.04	63.94	17.24
	1994-1998	19.25	23.11	7.83	68.77	13.40
	1998-2002	53.54	31.37	30.83	-5.97	6.25
	2002-2006	24.25	26.26	30.63	64.80	33.54
	2006-2009	-4.77	10.50	15.66	-91.55	29.56
Textile and leather	1990-1994	199.47	33.17	19.80	-6.17	-34.70
	1994-1998	316.76	24.12	8.99	8.09	-131.48
	1998-2002	-183.35	-5.45	36.10	116.70	-132.19
	2002-2006	-165.52	35.66	26.64	-12.15	283.23
	2006-2009	-67.36	12.50	8.48	-6.47	115.14
Construction	1990-1994	-436.43	3.81	19.36	0.00	-41.62
	1994-1998	-148.99	8.32	6.37	0.00	-24.37
	1998-2002	371.70	41.86	25.09	-170.75	64.61
	2002-2006	529.58	27.02	32.86	277.06	130.68
	2006-2009	-215.86	18.98	16.31	-6.31	-29.31
Transport Equipment	1990-1994	-54.25	4.68	2.01	3.79	22.75
	1994-1998	-137.79	-8.89	5.23	0.73	48.92
	1998-2002	1.97	30.74	29.88	196.87	10.35
	2002-2006	155.93	40.13	43.36	-59.98	20.71
	2006-2009	134.15	33.34	19.51	-41.42	-2.73
Iron and Steel	1990-1994	107.38	-177.49	18.06	44.74	22.61
	1994-1998	-57.30	-272.87	10.25	-103.14	9.98
	1998-2002	0.00	-1744.37	-18.51	0.00	59.77
	2002-2006	-15.92	1174.83	63.77	28.35	12.75
	2006-2009	65.85	1119.90	26.42	130.05	-5.11
Non ferrous metal	1990-1994	-4.25	-5.06	19.92	-2.76	2.59
	1994-1998	-11.67	-3.19	7.34	-0.48	-6.47
	1998-2002	2.78	-15.24	24.33	-50.12	4.68
	2002-2006	-5.41	31.43	26.65	-4.77	-2.58
	2006-2009	118.55	92.06	21.76	158.12	101.79
Non Metallic Minerals	1990-1994	-13.36	-10.46	19.98	-1.29	110.52
	1994-1998	-10.23	51.87	9.16	-8.80	-40.16
	1998-2002	40.07	8.23	33.40	20.65	76.09
	2002-2006	54.76	39.54	29.14	44.65	-17.67
	2006-2009	28.77	10.82	8.31	44.80	-28.79