Effect of Technology Change on CO_2 Emission in Japan's Industrial Sectors in the Period 1995-2005: An Input-Output Structural Decomposition Analysis

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ABSRACT:

This paper employs two-stage input-output structural decomposition analysis (SDA) to identify the factors responsible for changes in Japan's CO_2 emissions for two periods: 1995–2000 and 2000-2005. First, the study decomposes the total change in CO_2 emissions for each period to obtain the contribution of change in CO_2 emissions per unit output (CO_2 emissions coefficient), change in technology (technology effect), and change in final demand. The study observed from the first-stage decomposition that emission coefficient and final demand drives the change in the first period (1995-2000) while the technology effect drives the change in the second period (2000-2005). The high contribution of the technology effect is driven by activities of Iron & steel; Coke, refined petroleum & gas; Road Transportation; and Electricity sectors. Having observed the trend of the technology effect across the two periods, the study carried out a second-stage decomposition on technology effect in the second period to examine the contribution of each sector and observed that Chemical and pharmaceuticals; Iron & steel; Road Transportation; and Construction sectors are mainly responsible. In conclusion, improvement in technical efficiency especially at the industrial process level of each of the industries will help Japan achieve greater level of CO_2 emissions reduction.

Keywords: *CO_2 emissions, input-output, structural decomposition analysis, technological change, Japan*

LIST OF ABBREVIATIONS			
CO_2	Carbon dioxide	**JISF**	Japan Iron and Steel Federation
GHG	Greenhouse Gas	**KP**	Kyoto Protocol
GIO	Greenhouse Gas Inventory Office	**MOE**	Ministry of Environment
GWEC	Global Wind Energy Council	**NIES**	National Institute for Environmental Studies
IEA	International Energy Agency	**OECD**	Organization for Economic Co-operation and Development
IDA	Index Decomposition Analysis	**SDA**	Structural Decomposition Analysis
IEEJ	Institute of Energy Economics, Japan	**UNFCCC**	United Nations Framework Convention on Climate Change

1.0 INTRODUCTION

The Kyoto Protocol (KP) established in 1997 under the United Nations Framework Convention on Climate Change (UNFCCC) which entered into force in 2005 committed industrialized nations[1] to cut down greenhouse gas (GHG) emissions by at least 5% in the period 2008-2012 compared to the 1990 level (UNFCCC, 1998). Recent Conferences of

[1]Annex 1 Countries include the industrialised countries that where members of the Organisation for Economic Co-operation and Development (OECD) in 1992, plus countries with economies in transition (the EIT parties), including the Russian Federation, the Baltic States, and several Central and Eastern States.

Parties (COP)[2] have sought to establish a post-2012 commitment on GHG reductions by industrialized nations (UNFCCC, 2007, 2009). The 2012 Conference of Parties (in Doha, Qatar) contained an amendment to the initial Kyoto Protocol[3] which has a second commitment period running from 2012 until 2020, but limited the target of global CO_2 emissions to 15 percent due to lack of commitments of some countries (such as Japan), and due to the fact that some emerging economies like China, India, and Brazil are not subject to emissions reductions under the KP (UNFCCC, 2012). In the first phase of the KP, Japan was required to reduce emissions by 6% while United States and the European Union (EU) were to reduce by 7% and 8% respectively. However, the Protocol did not provide specific guidelines to the participating countries on the sectoral allocation of these targets but it required each country to establish pathways to help in achieving its target. Consequently, the Japanese government developed the Kyoto Protocol Target Achievement Plan in 1998 (revised in March 2002, April 2005, and March 2008) to explore measures to reduce GHG emissions (IEEJ, 2008). At the end of the first phase of the KP (in year 2012), UNFCCC (2011)[4] indicates that Japan's CO_2 emissions are increasing. In 2008, Japan's emissions stood at 1.28 billion tons (CO_2 equivalent) representing about 6.2% increase compared to 1990 level, showing a gap of 12.2% compared to the country's emission reduction target. However, the emissions reduced by 5.6% to 1.21 billion tonnes of CO_2 equivalents in the following year (NIES, 2009) which was attributed to the continuous decrease in energy demand within all sectors as a result of the economic recession induced by the financial crisis that occurred in second half of 2008 (MOE, 2011). A breakdown of the sectoral contribution to the overall decrease in GHG emissions from energy use in 2009 compared to the 2008 level shows a 7.5% decrease in the Industrial sectors (factories, etc.), 2.5% in transport, while energy industries, residential and other sectors (commerce, service, office etc.) decreased by 1.1%, 5.5% and 7.8% respectively.

Given that CO_2 has remained the dominant GHG in Japan with its share increasing from 91% in 1990 to 95% in 2008 (GIO, 2011), targeting reduction in CO_2 will have a greater impact on GHG reduction. Thus, there is need to analyse the sources of change in CO_2 emissions since this will help policy makers in designing a pathway for achieving greater reduction in GHGs. The objective of this study is to identify and analyse the factors responsible for changes in

[2] 2007 and 2009 United Nations Climate Change conferences in Bali, Indonesia and Copenhagen, Denmark respectively
[3] The amendment will enter into force after ratification by member states
[4] These are the most recent data on Japan available

Japan's CO_2 emissions for two periods: 1995–2000 and 2000-2005 with a view of making recommendations on where to target to achieve the set target. Consequently, the study employs a more recent methodology of two-stage input-output structural decomposition analysis (SDA) suggested by Miller & Blair (2009). First, the study decomposes the total change in CO_2 emissions to obtain the contribution of CO_2 coefficient, technology, and final demand. Thereafter, the technology effect is decomposed to obtain the contribution of each sector to the technology effect. The two-stage SDA approach employed in this study differs from most other studies which carry out only the first-stage decomposition of the total change in CO_2 emissions and also differs from the more popular RAS methodology of decomposing technology change.

The paper is organized as follows: after this brief introduction, section two reviews some literature, and the methodology is presented in section three. Section four discusses the results while section five provides some concluding remarks.

2.0 LITERATURE REVIEW

Researches in energy economics have extensively used decomposition techniques to analyse changes in energy consumption and GHG emissions between two or more periods e.g. Ang & Choi, 1997; Bhattacharyya & Ussanarassamee, 2004; Kojima & Bacon, 2009; Kagawa & Inamura, 2001; Lim *et al.*, 2009; Butner & Llop, 2001; etc. These studies are useful for understanding the methods of decomposition to explore and the relative contribution of different factors affecting the changes in GHG emission. Two prominent decomposition techniques are the index decomposition analysis (IDA) and the structural decomposition analysis (SDA). The IDA uses sector level data to decompose changes in indicators and has been used in several studies (Chung & Rhee, 2001; Ang, 2004; Paul & Bhattacharya, 2004; Luukkanen & Kaivo-oja, 2002; Liu *et al.*, 2007; Ma & Stern, 2008; Bhattacharyya & Matsumura, 2010) while the SDA uses the input-output data which are in disaggregated sector-level to decompose changes in indicators (Rose & Chen, 1991; Lin & Polenske, 1995; Hoekstra & van der Bergh, 2002; De Haan, 2001; Cheng *et al.*, 2008; Peng & Shi, 2011). The result of such decomposition identifies the relative contribution of the various sectors/activities of an economy to the total change in the economy. In a comparative study, Hoekstra & van der Bergh (2003) noted that SDA is capable of more refined decompositions of economic variable and technological effects while IDA allows for detailed time and country study because of the availability of data. The study further identified some differences between both methods, showed transferability of techniques, and concluded that multiple methods can be applied to single problem to generate a variety of perspectives on the various effects under study. Moreover, Rose & Casler (1996) carried out a comprehensive review of the input-output SDA and argues that the impact of direct and indirect effects captured in the input-output model gives SDA an edge over IDA which only captures the impact of direct effect. More recent review of the SDA development and applications has been carried out by Su & Ang (2012).

Some studies that have employed SDA in examining the sources of change in CO_2 emissions include Casler & Rose (1998); Wier (1998), Mukhopahyay (2001), Wood (2009), Zhang (2009). Casler & Rose (1998) refined the traditional SDA methodology by incorporating elements of the microeconomic production function – capital, labour, energy, and material aggregates (KLEM) – to examine the impact of various influences on CO_2 emssions in the US economy. The incorporation of the KLEM model into SDA allows for the estimation of the impacts of input-substition and change in technology in the various sectors on changes in CO_2 emissions. Wier (1998) explored the anatomy of Danish energy consumption and emissions by investigating the changes in emissions of carbon dioxide, sulphur dioxide, and nitrogen oxide between 1966 and 1988. The result revealed that changes in production based emissions (emissions generated within the borders of Denmark as a result of energy use in production to meet demand in Denmark and abroad-the supply-side effect) were much greater than private consumption emissions (emissions generated due to consumer behaviour in Danish household whether the energy used in production is imported or domestically produced-the demand-side effect), and increased level of final demand was said to be responsible for the changes. The study concludes that conservation policies were not responsible for decrease in CO_2 emission. Mukhopahyay (2001) examined CO_2 emission from fossil fuel combustion, and its sources of change in India during 1973-1974 to 1996-1997. The paper identified variations in industrial value-added; changes in CO_2 intensity of various industries; changes in technical coefficient; changes in final demand of various industries; and total joint effects as the forces responsible for changes in emission. The result showed that changes in the rate of value-added and final demand throughout the period were responsible for the increase in CO_2 emissions, while CO_2 intensity effect and technical coefficient effect helped in reducing emission, and finally suggested energy conservation, clean energy technology and inter-fuel substitution as policy options.

van der Linden & Dietzenbacher (2000) applied the RAS procedure (also known as a "bi-proportional" matrix balancing technique) to examine the determinants of structural change in the European Union between 1965 and 1985. Their formulation showed how RAS may be used as a descriptive tool to decompose input-output coefficient changes i.e. changes in the matrix of technical coefficients, into the productivity effect, the average substitution effect, and the sector-specific substitution effect. Thus the study established the usefulness of the RAS method as a good descriptive tool in examining the technological change.

Wood (2009) analysed changes in the factors influencing GHG emissions by decomposing total emissions into a number of key determinants over a period of 30 years. At the macro-level, the model enabled the investigation of inter-relationships between and within sectors of the economy, levels of consumption, export, emission production, and population while the micro-level breakdown of the economic structure and energy use gave insight on the sectors of the economy which are most responsible for emission growth. Zhang (2009) analysed historical changes in energy related carbon intensity in China between 1992 and 2006 and recommended that China enforce her policies on shaping the production pattern, such as reducing energy intensity and concentrate on increasing the sustainability of the demand pattern if it must succeed in decarbonising its economy.

Chang *et al.*(2008) employed input-output structural decomposition analysis to decompose CO_2 emissions changes in Taiwan into nine factors (industrial energy coefficient, CO_2 emission factor, inter-fuel substitution, rate of domestic production to intermediate input, structural change of intermediate input, level of domestic final demand, change of domestic final demand, level of exports, and structural change of exports) for the periods 1989-1994, 1994-1999, and 1999-2004. The study observed that the highest increase in CO_2 emissions in Taiwan was in the period 1999-2004 due to rapid increase in electricity consumption. Across the periods, the different factors contributed differently to the change in CO_2 emissions with energy coefficient and CO_2 emissions factors increasing from being minimally significant in the 1989-1994 period to becoming extremely important in the 1999-2004 period, joining domestic final demand and the level of exports as the major factors contributing to increase in CO_2 emissions in Taiwan. The study also highlighted some relevant strategies for reducing CO_2 emissions from industries. Similarly, Lim *et al.* (2009) examined the sources of change in CO_2 emissions in Korea between 1990 and 2003 using input-output structural decomposition analysis and decomposed change in CO_2 emissions into eight factors: changes in emission coefficient (caused by shifts in energy intensity and carbon intensity); changes in economic growth; and structural changes (in terms of shifts in domestic final demand, exports, imports of final and intermediate goods, and production technology). The result of the study indicated that increase in CO_2 emissions within the period was driven mainly by economic growth.

Peng & Shi (2011) employed input-output structural decomposition analysis to decompose CO_2 emissions growth from energy consumption in China between 1992 and 2005 into four (4) categories of factors: CO_2 emissions intensity, technology, domestic final demand, and trade. The study observed that increase in CO_2 emissions is driven mainly by domestic final demand and CO_2 emissions intensity played a restraining effect mainly because of benefits from energy efficiency, rather than energy substitution. Butnar & Llop (2011) applied structural decomposition analysis to an input-output subsystem representation to examine the sources in change in CO_2 emissions of Spanish service sectors. The study revealed that service sectors increased their CO_2 emissions mainly because of an increase in emissions generated by non-service sectors to cover the final demand for services.

Other studies that have employed input-output structural decomposition analysis in examining the sources of change in CO_2 emissions include Yih & Lin (1998), Chang & Lin (2001), Zhang & Qi (2011), Peters *et al.* (2007), Baiocchi & Minx (2010), etc.

In addition, there have been some studies on Japan that have examined the effects of technology change or employed decomposition methodology. Han & Lakshmanan (1994) employed SDA to analyze structural changes in the Japanese economy on its energy intensity between 1975 and 1985 and found that rather than the effects of changes in technology, changes in final demand structure contributed more to reducing the energy intensity of the economy and observed that overall decline in the energy intensity of the economy was as a result of drastic shifts in the fuel mix of Japanese energy supply, in particular, the substitution of oil by natural gas. Kagawa & Inamura (2001) examined the sources of the change in Japan's energy use structure between 1985 and 1990 and observed that the total energy requirement has increased, mainly because of the changes in the non-energy final demand, while the product-mix changes have opposite effects.

Yabe (2004) examined the effects of environmental technology changes (ETC) and production technology changes (PTC) in Japan between 1985 and 1995 using input-output analysis. The study further employed backward and forwarded linkage in each sector to calculate the extent to which each sector spreads or receive CO_2 emissions across all sectors and observed that both types of technologies contributed to a decrease in CO_2 emissions during the bubble economy of the late 1980s but not during the recession of the early 1990s. Okushima & Tamura (2011) examined the sources of change in energy use or CO2 emissions in Japan between 1970 and 1990 using SDA and multiple calibration decomposition analysis- a newer methodology in decomposition. The study investigated the properties of both methodologies by empirically applying them to Japan and concluded that "understanding the theoretical properties of decomposition methodologies is essential for a precise interpretation of empirical results".

Advancements in input-output SDA have extended the traditional SDA methodology to be able to dig deeper to identify the sources of change of variables (e.g. CO2 emissions) in the economy or to trace the path of change of such variables. Some of these advancements include the two-stage SDA (Miller & Blair, 2009) and structural path decomposition (Wood & Lenzen, 2009; Oshita, 2012). Two-stage SDA digs deeper to identify the relative contribution of different sectors to change in a period, however, it does not identify the specific path in which the changes occur. Structural path decomposition (SPD) traces the path where change in variables occur over time by integrating the ability of structural path analysis (SPA)[5] in identifying important paths of change in variables in an input-output table with SDA. Oshita (2012) applied structural path decomposition (SPD) on Japanese environmental input-output tables to identify critical supply chain paths that drive changes in CO_2 emissions in Japan between 1990 and 2000 and observed, among other things, that the volume of CO_2 emissions increased as a result of changes in the input structure of the electricity of the services sector.

3.0 METHODOLOGY

This study follows the structural decomposition analysis methodology explained in Miller & Blair (2009), pp. 593-621. First, we note that sectoral CO_2 emissions for any year may be expressed as a function of sectoral gross output, and in-turn, a function of the Leontief inverse matrix and final demand vector. Thus, given the set of emissions coefficient - CO_2

[5] The methodological underpinning of structural path analysis (SPA) involves carrying out a Taylor's expansion of the Leontief inverse matrix, $(I-A)^{-1}$, such that changes in key variables may be observed at the process level instead of country level aggregates. However, SPA is applied statically, so when combined with SDA as in structural path decomposition, it provides a robust method for tracing the path of change in variables over time. Methodological development of SPA can be found in Lenzen (2003). SPD and SPA are different to two-stage SDA which only performs a second-level decomposition of the effects obtained from the traditional SDA decomposition.

emissions per unit output in sector j at time t, (e_j^t), let $(e^t)' = [e_1^t, \ldots, e_n^t]$. The vector of CO_2 emissions, by sector, associated with output at t will be:

$$\boldsymbol{\varepsilon^t} = \hat{\mathbf{e}}^{\boldsymbol{t}} x^t = \hat{\mathbf{e}}^{\boldsymbol{t}} \boldsymbol{L^t} f^t \qquad \ldots (1)$$

Where $\hat{\boldsymbol{e}}$ is $n \; x \; n$ diagonal matrix with the diagonal elements being $e_j s$, x is the gross output column vector, $\boldsymbol{L}$ is the Leontief inverse matrix, and f is the vector of final demand.

The first stage decomposition seeks to obtain the contribution of three factors – emissions coefficient, technology, and final demand to the changes in sectoral CO_2 emissions between two given years. Several decomposition forms are possible but as noted by Dietzenbacher & Los (1998) the average of two polar decompositions is an acceptable approach. So we compute the change in CO_2 emissions using the average of two polar decompositions as follows:

$$\boldsymbol{\Delta\varepsilon} = \boldsymbol{\varepsilon^1} - \boldsymbol{\varepsilon^0} = \hat{\mathbf{e}}^{\mathbf{1}} \boldsymbol{L^1} f^1 - \hat{\mathbf{e}}^{\mathbf{0}} \boldsymbol{L^0} f^0 \qquad \ldots (2)$$

Through basic algebraic manipulation of equation (2) by substituting $\hat{\mathbf{e}}^{\mathbf{1}}, \boldsymbol{L^1}, f^1, \hat{\mathbf{e}}^{\mathbf{0}}, \boldsymbol{L^0}$, or f^0 with $\boldsymbol{\Delta L} = \boldsymbol{L^1} - \boldsymbol{L^0}$, $\Delta f = f^1 - f^0$, or $\boldsymbol{\Delta\hat{e}} = \hat{\mathbf{e}}^{\mathbf{1}} - \hat{\mathbf{e}}^{\mathbf{0}}$ we can express equation (2) as[6]

$$\boldsymbol{\Delta\varepsilon} = \boldsymbol{\Delta\hat{e}}\, \boldsymbol{L^0} f^0 + \hat{\mathbf{e}}^{\mathbf{1}} \boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}} \boldsymbol{L^1} \Delta f \qquad \ldots (3)$$

or

$$\boldsymbol{\Delta\varepsilon} = \boldsymbol{\Delta\hat{e}}\, \boldsymbol{L^1} f^1 + \hat{\mathbf{e}}^{\mathbf{0}}\, \boldsymbol{\Delta L} f^1 + \hat{\mathbf{e}}^{\mathbf{1}} \boldsymbol{L^0} \Delta f \qquad \ldots (4)$$

Although equations (3) and (4) are "mathematically correct" given the definitions of $\boldsymbol{\Delta L} = \boldsymbol{L^1} - \boldsymbol{L^0}$, $\Delta f = f^1 - f^0$, and $\boldsymbol{\Delta\hat{e}} = \hat{\mathbf{e}}^{\mathbf{1}} - \hat{\mathbf{e}}^{\mathbf{0}}$ their values will differ as they measure different things[7] [see Miller & Blair (2009), p. 594]. Thus, the average is taken and we have

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[6] equation (3) is obtained by substituting $\boldsymbol{L^1} = \boldsymbol{L^0} + \boldsymbol{\Delta L}$, $f^1 = f^0 + \Delta f$, and $\hat{\mathbf{e}}^{\mathbf{0}} = \hat{\mathbf{e}}^{\mathbf{1}} - \boldsymbol{\Delta\hat{e}}$ in equation (2) to get

$\boldsymbol{\Delta\varepsilon} = \hat{\mathbf{e}}^{\mathbf{1}}(\boldsymbol{L^0} + \boldsymbol{\Delta L})(f^0 + \Delta f) - (\hat{\mathbf{e}}^{\mathbf{1}} - \boldsymbol{\Delta\hat{e}})\boldsymbol{L^0} f^0$

$= \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^0} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^0}\Delta f + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L}\,\Delta f - \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^0} f^0 + \boldsymbol{\Delta\hat{e}}\boldsymbol{L^0} f^0$

$= \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^0}\Delta f + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L}\,\Delta f + \boldsymbol{\Delta\hat{e}}\boldsymbol{L^0} f^0$. By rearranging we have

$= \boldsymbol{\Delta\hat{e}}\boldsymbol{L^0} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^0}\Delta f + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L}\,\Delta f$

$= \boldsymbol{\Delta\hat{e}}\boldsymbol{L^0} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}(\boldsymbol{L^0} + \boldsymbol{\Delta L})\,\Delta f = \boldsymbol{\Delta\hat{e}}\boldsymbol{L^0} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L} f^0 + \hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^1}\Delta f$

Similarly, equation (4) is obtained by substituting $\hat{\mathbf{e}}^{\mathbf{1}} = \hat{\mathbf{e}}^{\mathbf{0}} + \boldsymbol{\Delta\hat{e}}$; $\boldsymbol{L^0} = \boldsymbol{L^1} - \boldsymbol{\Delta L}$, and $f^0 = f^1 - \Delta f$ into equation (2)

$$\boldsymbol{\Delta\varepsilon} = \left(\frac{1}{2}\right)(\boldsymbol{\Delta\hat{e}})[\boldsymbol{L^0}f^0 + \boldsymbol{L^1}f^1] + \left(\frac{1}{2}\right)\left[\hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L}f^0 + \hat{\mathbf{e}}^{\mathbf{0}}\boldsymbol{\Delta L}f^1\right] + \left(\frac{1}{2}\right)\left[\hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{L^1} + \hat{\mathbf{e}}^{\mathbf{0}}\boldsymbol{L^0}\right](\Delta f) \quad \ldots(5)$$

each vector on the right hand side of equation (5) captures the ***emission coefficient effect***, ***technology effect,*** and ***final-demand effect*** respectively.

The change in the Leontief inverse matrix (**ΔL**) which represents the change in technology is a result of change(s) in the matrix of technical coefficient (**A**) which reflects change(s) in the production recipe of one or more sectors in the economy (this may be as a result of change in productivity level, change in relative price level, input substitution etc). Our objective is to identify the sectors that drive change in the matrix of technical coefficient (**A**).Some studies have used the RAS method in decomposing **ΔA** (van der Linden & Dietzenbacher, 2000; Lu & Xu, 2012). In this study, we use an alternative method by disaggregating **ΔA** into column-specific changes only. We note that each column in **A** reflects a sector's production recipe thereforeidentifying the column-by-column changes is one way of disentangling the effects of input changes in each of the sectors in the economy [see Miller & Blair (2009), p. 604]. To obtain the contribution of each sector to the change in the technological structure of the economy, we carry out the second stage decomposition by decomposing the ***technology effect*** to identify the contribution of each sector. We note that the ***technology effect*** depends on changes in the Leontief inverse between the two periods, (**ΔL**), which also reflects changes in the underlying direct input matrices (**ΔA)**. We need to translate **ΔA** into **ΔL.** We proceed using multiplicative decomposition as follows.

Given $\boldsymbol{L^1} = (\boldsymbol{I} - \boldsymbol{A^1})^{-1}$, and $\boldsymbol{L^0} = (\boldsymbol{I} - \boldsymbol{A^0})^{-1}$, post-multiply $\boldsymbol{L^1}$ by $(\boldsymbol{I} - \boldsymbol{A^1})$ and pre-multiply $\boldsymbol{L^0}$ by $(\boldsymbol{I} - \boldsymbol{A^0})$ such that we have

$$\boldsymbol{L^1}(\boldsymbol{I} - \boldsymbol{A^1}) = \boldsymbol{I} = \boldsymbol{L^1} - \boldsymbol{L^1}\boldsymbol{A^1} \quad \ldots(6)$$

and

$$(\boldsymbol{I} - \boldsymbol{A^0})\boldsymbol{L^0} = \boldsymbol{I} = \boldsymbol{L^0} - \boldsymbol{A^0}\boldsymbol{L^0} \quad \ldots(7)$$

Rearrange equation (6) and post-multiply by $\boldsymbol{L^0}$

[7] For example the first term in equation (3) i.e. $\boldsymbol{\Delta}\hat{e}\,\boldsymbol{L^0}f^0$ captures the effect of change CO2 emission coefficient relative the technological structure and final demand of year 0 while the first term in equation (4) i.e. $\boldsymbol{\Delta}\hat{e}\,\boldsymbol{L^1}f^1$ captures the effect of change in CO2 emission coefficient relative to the technological structure and final demand of year 1.

$$\boldsymbol{L^1 - I = L^1A^1 \Rightarrow L^1L^0 - L^0 = L^1A^1L^0} \qquad ...(8)$$

Rearrange equation (7) and pre-multiply by $\boldsymbol{L^1}$

$$\boldsymbol{L^0 - I = A^0L^0 \Rightarrow L^1L^0 - L^1 = L^1A^0L^0} \qquad ...(9)$$

Subtracting equation (9) from equation (8), we have

$$\boldsymbol{\Delta L = L^1 - L^0 = L^1A^1L^0 - L^1A^0L^0 = L^1(\Delta A)L^0} \qquad ...(10)$$

Now, we need to decompose $\boldsymbol{\Delta A}$. Changes in the matrix of technical coefficient, $\boldsymbol{A}$, means changes in some, or all of the columns making up $\boldsymbol{A}$ which may be regarded as changes in the production recipe of the industries. Thus, we need to identify the changes column by column so as to disentangle the effects of input changes in each industry. For our n sector economy,

$$\boldsymbol{A^1 = A^0 + \Delta A} = \begin{bmatrix} a_{11}^0 + \Delta a_{11} & \cdots & a_{1n}^0 + \Delta a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1}^0 + \Delta a_{n1} & \cdots & a_{nn}^0 + \Delta a_{nn} \end{bmatrix}$$

Let $\boldsymbol{\Delta A(j)} = \begin{bmatrix} 0 & ... & \Delta a_{1j} & ... & 0 \\ \vdots & ... & \vdots & ... & \vdots \\ 0 & ... & \Delta a_{nj} & ... & 0 \end{bmatrix}$

Represent the changes in sector $j's$ technology. Then,

$$\boldsymbol{\Delta A} = \Delta A(1) + \Delta A(2) + ... + \Delta A(j) + ... + \Delta A(n) = \sum_{j=1}^{n} \Delta A(j) \qquad ...(11)$$

Substituting equation (11) in (10) and putting the resulting equation in equation (5), the ***technology change*** can be expressed as

$$\textbf{\textit{Technology effect}} = \left(\frac{1}{2}\right)[\hat{\mathbf{e}}^{\mathbf{1}}\boldsymbol{\Delta L}f^0 + \hat{\mathbf{e}}^{\mathbf{0}}\boldsymbol{\Delta L}f^1]$$

$$= \left(\frac{1}{2}\right)[\hat{\mathbf{e}}^{\mathbf{1}}(\boldsymbol{L^1\Delta AL^0})f^0 + \hat{\mathbf{e}}^{\mathbf{0}}(\boldsymbol{L^1\Delta AL^0})f^1]$$

$$= \left(\frac{1}{2}\right)\left[\hat{\mathbf{e}}^{\mathbf{1}}\left(\boldsymbol{L^1}\sum_{j=1}^{n}\Delta A(j)\,\boldsymbol{L^0}\right)f^0 + \hat{\mathbf{e}}^{\mathbf{0}}\left(\boldsymbol{L^1}\sum_{j=1}^{n}\Delta A(j)\,\boldsymbol{L^0}\right)f^1\right]$$

…(12)

where the jth colunm in equation (12) represents the contribution of sector j to ***technology effect*** vector. In addition, the ith element in the jth column in equation (12) represents the contribution of the sector j to the technology change of sector i in the ***technology effect*** vector. By extension, since the first stage decomposition effects (i.e. CO_2 emissions coefficient, technology, and final demand effects) are commonly viewed relative to the total CO_2 emissions of year 0, and given that adding up all the *ij*th elements in the equation (12) gives the ***technology effect*** (i.e. the sum of the elements in the ***technology effect*** vector), it follows that dividing each *ij*th element in equation (12) by the total CO_2 emissions in year 0[8] gives the relative change in CO_2 emissions from change in technical requirement of sector *i* from sector *j* relative to year 0.

3.1 DATA CONSOLIDATION

The study employed input-out tables for Japan (in Yen) for the years 1995, 2000 and 2005 obtained from the website of the Organization for Economic Cooperation and Development (OECD, 2011) and CO_2 emissions data (in million tonnes) from Greenhouse gas Inventory of Japan (GIO, 2011). The CO_2 emissions data had 19 sectors while the I-O tables had forty eight (48) sectors. The 48-sector I-O tables were aggregated to 19 sectors to be compatible with the CO_2 emissions data using the United Nations International Standard Industrial Classification as a guide. Since I-O tables are presented in current prices, the tables for years 2000 and 2005 were adjusted to 1995 prices using the consumer price index (CPI) of Japan from the World Bank's database.

4.0 RESULTS & DISCUSSIONS

The results of the decomposition of total change in CO_2 emission for the two periods are presented in tables 1 and 2 respectively.

[8] Dividing a matrix by a constant implies dividing each element in the matrix by the constant

Table 1: Result of decomposition of total change in CO_2 emissions between 1995 and 2000

Industry	EFFECTS					
	Emissions coefficient effect	Technology Effect	Final demand Effect	Total Change	CO2 emissions in 1995	Contribution of sector to total Change within the period
1 Agriculture, hunting, forestry and fishing	-3206.973	-1575.499	1463.931	-3318.541	19525.590	-63.64
2 Mining and quarying (energy and non energy)	183.936	266.993	-467.959	-17.030	868.980	-0.33
3 Food products, beverages and tobacco	-310.532	-346.001	-589.350	-1245.883	14407.326	-23.89
4 Pulp, paper, paper products, printing and publishing	95.685	-2535.571	2026.176	-413.710	29448.800	-7.93
5 Coke, refined petroleum & gas	-9307.007	-3648.899	12978.280	22.375	42002.257	0.43
6 Chemical and phamaceuticals	-12682.187	-1895.658	6661.533	-7916.311	79025.770	-151.80
7 Other non-metallic mineral products	1034.967	-9881.665	-3825.314	-12672.012	104146.612	-243.00
8 Iron & steel	21804.755	-27869.503	14979.210	8914.462	141862.011	170.94
9 Non-ferrous metals	-1868.909	-878.832	1019.358	-1728.383	4769.900	-33.14
10 Fabricated metal products, except machinery & equipment	-59.660	-42.938	-6.202	-108.800	357.222	-2.09
11 Matchinery & Equipment	-10775.554	406.134	425.011	-9944.409	18624.180	-190.69
12 Road Transportation	5169.053	-10595.953	12872.802	7445.901	225381.449	142.78
13 Railroad equipment & transport equip nec.	143.506	-128.647	-126.944	-112.085	819.364	-2.15
14 Electricity	33447.065	-34017.524	16033.801	15463.343	315399.266	296.53
15 Other industries	15679.543	-2762.983	-3045.710	9870.850	39332.690	189.28
16 Construction	-445.395	24.557	-1818.069	-2238.907	16261.574	-42.93
17 Water Transport, building and repairs of ships and boats	724.053	-333.805	-213.038	177.211	14687.422	3.40
18 Aircraft& Spacecraft and Air transport	-1537.511	328.751	1607.600	398.840	10278.291	7.65
19 Commercial/Institutional	-7094.277	5416.402	4315.795	2637.920	66320.358	50.58
Total	30994.559	-90070.640	64290.913	5214.832	1143519.062	
Contribution of effect to total change within the period	594.35	-1727.20	1232.85			
Percentage relative to total CO2 emissions in 1995	2.71	-7.88	5.62			

Table 2: Result of decomposition of total change in CO_2 emissions between 2000 and 2005

Industry	EFFECTS					
	Emissions coefficient effect	Technology Effect	Final demand Effect	Total Change	CO2 emissions in 2000	Contribution of sector to total Change within the period
1 Agriculture, hunting, forestry and fishing	2062.748	0.912	-3112.379	-1048.719	16207.049	-4.552
2 Mining and quarying (energy and non energy)	-369.036	9553.852	-9309.732	-124.917	851.950	-0.54
3 Food products, beverages and tobacco	-1966.457	599.857	-468.710	-1835.310	13161.443	-7.97
4 Pulp, paper, paper products, printing and publishing	1553.185	-989.790	-3046.579	-2483.184	29035.090	-10.78
5 Coke, refined petroleum & gas	-5207.556	**21360.385**	-11235.771	4917.059	42024.632	21.34
6 Chemical and phamaceuticals	-11370.719	9089.285	-7291.265	-9572.699	71109.459	-41.55
7 Other non-metallic mineral products	16448.635	-3936.888	-17986.244	-5474.496	91474.600	-23.76
8 Iron & steel	-40905.843	**54357.417**	-11487.318	1964.256	150776.473	8.53
9 Non-ferrous metals	-1405.045	1761.287	-764.046	-407.804	3041.517	-1.77
10 Fabricated metal products, except machinery & equipment	19.467	31.112	-57.071	-6.493	248.422	-0.03
11 Matchinery & Equipment	1386.925	170.363	-932.594	624.694	8679.771	2.71
12 Road Transportation	-32226.054	**17911.831**	4139.055	-10175.168	232827.350	-44.17
13 Railroad equipment & transport equip nec.	-229.187	-58.701	224.319	-63.568	707.280	-0.28
14 Electricity	52471.910	**15029.661**	-19444.158	48057.414	330862.609	208.61
15 Other industries	12738.827	768.902	-9585.789	3921.940	49203.540	17.02
16 Construction	725.584	-124.940	-2652.929	-2052.286	14022.667	-8.91
17 Water Transport, building and repairs of ships and boats	-5187.146	1692.702	1544.784	-1949.660	14864.633	-8.46
18 Aircraft& Spacecraft and Air transport	-768.103	1680.334	-790.543	121.687	10677.131	0.53
19 Commercial/Institutional	3377.330	-3575.969	-1176.967	-1375.606	68958.278	-5.97
Total	-8850.535	125321.612	-93433.936	23037.141	1148733.894	
Contribution of effect to total change within the period	-38.42	544.00	-405.58			
Percentage relative to total emissions in 2000	-0.77	10.91	-8.13			

The result of the first period (1995-2000) shows that final demand effect contributed 64290.913 (1232.85%) to the total change in CO_2 emission (5214.832) in the period followed by emission coefficient effect [30994.559 (594.35%)], while technology contributed negatively [-90070.640 (-1727.20 %)]. From the result, we see that if the technology and final demand in 2000 were the same as in 1995, emission coefficient would have increased emission by 2.71%. Similarly, if emission coefficient and final demand in 2000 were the same as in 1995, technology would have reduced emission by 7.88%.

Considering the total effects by sector in the first period, four sectors are seen to be the highest contributors to increase in CO_2 emission. *Electricity* sector (296.53%) is the highest contributor followed by *other industries* (189.28%); *Iron & steel* (170.94%)*;* and *Road transport* (142.78%), while *other non-metallic mineral products; chemical & pharmaceutical;* and *machinery & equipment* helped to reduce emission. In all, eight sectors contributed to increase in emission while eleven sectors helped to reduce emission. Nevertheless, the total effect shows a positive change, implying that the increase from the eight sectors outweighs the reduction from the other eleven sectors. Examining the impact of the different effect on the sectors in the period 1995-2000, we observe that emission coefficient has reduced in *Chemical & pharmaceutical; Machinery & equipment*; *Coke refined petroleum & gas;* and *Commercial/Institutional* sectors, while it increased the most in *Electricity* sector. Technology effect reduced the most in *Electricity*, followed by *Iron & steel*; *Road transport;* and *other non-metallic mineral* sectors. Final demand effect reduced the most in *non-metallic minerals*; *Construction*; and *other Industries*.

Moving on to the second period (2000-2005), we observe that emission coefficient would have reduced emission by 0.77% if technology and final demand in 2005 was the same as that of 2000. Final demand would have also reduced emission by 8.13% if emission coefficient and technology in 2005 remained the same as in 2000, while technology would have increased emission by 10.91% if final demand and emission coefficient in 2005 was the same as that of 2000. Furthermore, the total effect by sectors in the second period shows four sectors to be the highest contributors to emission. *Electricity* sector is the highest with 208.61%, followed by *coke refined petroleum & gas* (21.34%); *other industries* (17.02%); and *Iron & steel* (8.53%), while sectors like *road transport;* and *chemical & pharmaceutical* helped to reduce emission. Similarly, we observe that emission coefficient reduced most in *Iron & steel* followed by *Road transport*; *Chemical & petrochemicals;* and *Coke, refined petroleum & gas* sectors. Technology effect reduced only in five sectors while the remaining fourteen sectors had positive technology effect with *Iron & steel* recording the highest followed by *Coke refined petroleum & gas*; *Road transport;* and *Electricity.* Final demand effect reduced in sixteen sectors with *Non- metallic mineral products*; and *Electricity* showing the highest reduction.

In conclusion, the result of our first-stage decomposition indicates that total change in CO_2 emissions in the first period is driven by emission coefficient effect and final demand effect. In contrast, the total change in CO_2 emissions in the second period is driven by technology effect. The shift in technology effect from negative to positive may be a reflection changes in final demand pattern[9] (due to increase in export demand for Japanese products or increase in household demand). For example, Oshita (2012) noted that rise in demand for exports of integrated circuits contributed to increase in emissions generated from the *Electricity* sector between 1990 and 2000.

Comparing the technology effect in the first stage decomposition for both periods, we observe that while technology effect contributed negatively to the total change in the first period, it shows a positive contribution in the second period. Hence, the second stage decomposition is geared towards identifying the contribution of each sector to the under-performance of technology effect in the second period. The result of the sectors with the highest contribution to the technology effect (*Coke refined petroleum & gas*, *Iron and steel*, *Road transport,* and *Electricity*) is presented in table 3[10]. The complete result of the second-stage decomposition of technology is presented in appendix B.

The second-stage decomposition of technology effect in the second period reveals that *Commercial/Institutional; Road transport; Chemical and pharmaceutical;* and *Construction* are the major sources of the under-performance of technology in the *Coke, refined petroleum & gas* sector. This reflects a relative increase in the technical requirement of the inputs of these sectors to the *Coke, refined petroleum & gas* sector. The high contribution of technology change in *Commercial/Institutional* is a sum of changes in the fourteen sectors that were aggregated from the original I-O table to form the sector. Therefore, isolating the individual sectors will provide a better picture of the impact of these sectors on the

[9] The final demand pattern refers to the overall change in the final demand component of the the input-output matrix which may be as a result of change in the overall *level* of final demand or change in the relative proportions of expenditure on the various goods and services in the final-demand vector (the final-demand *mix*)
[10] The table has been transposed for ease of presentation. The transposed rows are highlighted in the complete result in appendix B. Observe that the totals in the last row in Table 3 are exactly the same as the values for *coke, refined petroleum and gas*; *iron and steel*; *road transport;* and *electricity* which are in bold in the technology effect column in Table 2.

technological change in *Coke, refined petroleum & gas* sector. This will be possible if the study is carried out at a more disaggregated level given the availability of CO_2 data[11]. Thus, programmes to reduce CO_2 emissions in the *Coke, refined petroleum & gas* sector will be more effective if the sectors responsible for the poor performance are targeted.

Table 3: Second level decomposition of technology change 2000-2005

Industry	*5 Coke,refined petroleum, manufacture and distribution of gaseous fuel and nuclear fuel*	*8 Iron & steel*	*12 Road Transportation (motor vircles, trailers and auxillary transport activities)*	*14 Production, collection and distribution of electricity*
1 Agriculture, hunting, forestry and fishing	585.426	-14.353	425.536	258.366
2 Mining and quarying (energy and non energy)	-793.346	55.338	-89.878	165.571
3 Food products, beverages and tobacco	625.840	-449.071	**881.945**	1092.886
4 Pulp, paper, paper products, printing and publishing	463.079	-343.597	385.071	140.917
5 Coke, refined petroleum & gas	27.184	268.087	679.199	468.559
6 Chemical and phamaceuticals	**2249.859**	-486.225	**796.357**	**3032.624**
7 Other non-metallic mineral products	420.118	17.119	300.863	739.876
8 Iron & steel	1085.132	**25160.216**	273.851	**2692.603**
9 Non-ferrous metals	177.774	-355.235	-162.479	-141.137
10 Fabricated metal products, except machinery & equipment	267.895	7833.991	190.743	1097.082
11 Matchinery & Equipment	561.670	**11068.715**	-751.387	**4258.043**
12 Road Transportation	**2920.966**	**3167.933**	**15111.346**	491.859
13 Railroad equipment & transport equip nec.	22.949	945.979	52.499	115.763
14 Electricity	1314.826	470.708	645.555	493.614
15 Other industries	1424.601	1034.284	-251.615	**2308.310**
16 Construction	**2235.144**	**9716.028**	**1427.725**	1728.739
17 Water Transport, building and repairs of ships and boats	561.303	3355.668	135.638	679.941
18 Aircraft& Spacecraft and Air transport	488.376	-256.391	-872.516	-92.068
19 Commercial/Institutional	**6721.590**	-6831.775	-1266.622	-4501.886
TOTAL	**21360.385**	**54357.417**	**17911.831**	**15029.661**

With respect to the *Iron & steel* sector, *Iron & steel; Machinery & equipment; Construction;* and *Fabricated metal products* sectors contributed most to the increased technology effect. This also reflects a relative increase in the technical requirement of the inputs of these sectors to the *Iron & steel* sector. Opportunity to reduce CO_2 emission in the *Iron & steel* sector lies mainly in material-use of the steel making process. While conscious efforts have been made by some companies in the sector to reduce CO_2 emissions through the development of environmentally-conscious technologies for the steel production process (Kawai, 2001), there is opportunity for further improvement especially by other companies in the *Iron & steel* sector. In particular, given that most steel companies in Japan rely on blast furnace technology for production (Kiko, 2008), the adoption of hydrogen-reduction of iron ore which generates H_20 instead of CO_2 in the blast furnace will help reduce CO_2 emission in the

[11] *Road transport; Chemical and pharmaceutical;* and *Construction* sectors are discussed in subsequent paragraphs

sector (Cockerill, 2011; JISF, 2011). Furthermore, the *Iron & steel* sector is energy intensive and uses much of coal and coke which emits much CO_2, thus, increasing energy efficiency at the process level in order to maximize heat use in the blast furnace will help in reducing demand for coal and coke which will in-turn reduce CO_2 emissions.

Considering the technological change in the *transportation* sector, we observed from the result that *Road Transportation; Construction; Food products, beverages and tobacco;* and *Chemical and pharmaceuticals* sectors contribute the most to the increase in technology effect between 2000 and 2005. This reflects a relative increase in the amount of input required from these sectors to produce one unit worth of output of *transportation* sector. Consequently, this leads to an increase in CO_2 emission from the sector. To reduce CO_2 emission due to technology effect in the *transportation* sector, the activities of these sectors need to be considered especially the contribution of the *transportation* sector to itself which accounts for 84% of total CO_2 emission. Therefore, improving fuel and vehicle efficiency in *transportation* sector will be an effective means of reducing CO_2 emission. Furthermore, given that gasoline has a high emission coefficient and its share in the energy mix of the road transport sector in 2009 was 66% (IEA, 2011), there is an opportunity to reduce CO_2 emission by switching to fuels with lower emission coefficient like liquefied petroleum gas or compressed natural gas.

For *electricity*, *Machinery & Equipment; Chemical and pharmaceuticals; other industries;* and *Iron & steel* sectors are mainly responsible for the increase in CO_2 emission due to technology effect. Between 2000 and 2005, Japan's electricity generation from wind turbines increased by 676% from 139MW to 1078MW (GWEC, 2006). Thus, increase in CO_2 emissions may not be unrelated to the increase in inputs gotten from these sectors since construction of wind turbines needs considerable amount of inputs from the *Machinery & Equipment;* and *Iron & steel* sectors. Reducing CO_2 emissions from the *Electricity* sector will require improving the technical efficiency in the sectors that contributes most to the high CO_2 emission in the *Electricity* sector.

5.0 CONCLUSION

This paper employed two-stage input-output structural decomposition analysis (SDA) to identify and analyse the factors responsible for changes in Japan's CO_2 emissions for two periods: 1995–2000 and 2000-2005. Two-stage decomposition is useful in obtaining the relative contribution of each sector of the economy to changes in CO_2 emissions due to industrial activities in a country, using inter-industry transactions as presented in an input-output table. First, the study decomposed the total change in CO_2 emissions to obtain the contribution of CO_2 coefficient, technology, and final demand. Thereafter, the technology effect was decomposed to obtain the contribution of each sector to the technology effect. In conclusion, improvement in technical efficiency especially at the industrial process level of industries in Chemical and pharmaceuticals; Iron & steel; Road Transportation; and Construction sectors will help Japan achieve greater level of CO_2 emissions reduction in industrial activities.

APPENDIX A: Classification of sectors

Aggregate Sector	Sectors in OECD I-O Table
1 Agriculture, hunting, forestry and fishing	1 Agriculture, hunting, forestry and fishing
2 Mining and quarying (energy and non energy)	2 Mining and quarrying (energy) 3 Mining and quarrying (non-energy)
3 Food products, beverages and tobacco	4 Food products, beverages and tobacco
4 Pulp, paper, paper products, printing and publishing	7 Pulp, paper, paper products, printing and publishing
5 Coke,refined petroleum & gas	8 Coke, refined petroleum products and nuclear fuel
6 Chemical and phamaceuticals	9 Chemicals excluding pharmaceuticals 10 Pharmaceuticals
7 Other non-metallic mineral products	12 Other non-metallic mineral products
8 Iron & steel	13 Iron & steel
9 Non-ferrous metals	14 Non-ferrous metals
10 Fabricated metal products	15 Fabricated metal products, except machinery & equipment
11 Matchinery & Equipment	16 Machinery & equipment, nec 17 Office, accounting & computing machinery 18 Electrical machinery & apparatus, nec 19 Radio, television & communication equipment 20 Medical, precision & optical instruments
12 Road Transportation	21 Motor vehicles, trailers & semi-trailers 33 Land transport; transport via pipelines 36 Supporting and auxiliary transport activities; activities of travel agencies
13 Railroad equipment & transport equip nec.	24 Railroad equipment & transport equip nec.
14 electricity	26 Production, collection and distribution of electricity 27 Manufacture of gas; distribution of gaseous fuels through mains
15 Other industries	5 Textiles, textile products, leather and footwear 6 Wood and products of wood and cork 11 Rubber & plastics products 25 Manufacturing nec; recycling (include Furniture) 28 Steam and hot water supply 29 Collection, purification and distribution of water
16 Construction	30 Construction
17 Water Transport, building and repairs of ships and boats	34 Water transport 22 Building & repairing of ships & boats
18 Aircraft& Spacecraft and Air transport	23 Aircraft & spacecraft 35 Air transport
19 Commercial/Institutional	31 Wholesale & retail trade; repairs 32 Hotels & restaurants 37 Post & telecommunications 38 Finance & insurance 39 Real estate activities 40 Renting of machinery & equipment 41 Computer & related activities 42 Research & development 43 Other Business Activities 44 Public admin. & defence; compulsory social security 45 Education 46 Health & social work 47 Other community, social & personal services 48 Private households with employed persons & extra-territorial organisations & bodies

Appendix B: Second stage decomposition of technology effect of all the sectors

Industry	1 Agriculture, hunting, forestry and fishing	2 Mining and quarying (energy and non energy)	3 Food products, beverages and tobacco	4 Pulp, paper, paper products, printing and publishing	5 Coke, refined petroleum & gas	6 Chemical and phamaceuticals	7 Other non-metallic mineral products	8 Iron & steel	9 Non-ferrous metals	10 Fabricated metal products, except machinery & equipment
1 Agriculture, hunting, forestry and fishing	330.590	7.821	590.195	-18.680	5.542	-43.431	-4.673	0.482	0.587	-14.340
2 Mining and quarying (energy and non energy)	122.461	-179.806	136.321	77.928	2773.221	354.900	225.868	482.218	330.988	117.318
3 Food products, beverages and tobacco	169.747	1.309	311.984	-4.092	3.775	-2.392	-0.684	-3.297	0.551	-1.418
4 Pulp, paper, paper products, printing and publishing	-23.167	8.614	56.864	511.996	19.780	106.517	44.936	-19.097	0.702	29.059
5 Coke, refined petroleum & gas	**585.426**	**-793.346**	**625.840**	**463.079**	**27.184**	**2249.859**	**420.118**	**1085.132**	**177.774**	**267.895**
6 Chemical and phamaceuticals	164.998	-12.367	-24.930	-253.793	-317.240	8804.174	50.900	72.755	50.974	-88.165
7 Other non-metallic mineral products	17.560	63.766	53.665	-128.774	-153.551	-264.114	-341.207	883.803	89.432	-29.200
8 Iron & steel	**-14.353**	**55.338**	**-449.071**	**-343.597**	**268.087**	**-486.225**	**17.119**	**25160.216**	**-355.235**	**7833.991**
9 Non-ferrous metals	3.296	-5.838	12.259	-12.922	-8.677	17.965	4.845	31.996	285.648	119.904
10 Fabricated metal products, except machinery & equipment	0.118	-0.718	-0.152	-0.381	1.131	0.622	-0.015	-0.741	-0.079	0.884
11 Matchinery & Equipment	12.280	-6.558	14.516	1.630	18.184	19.823	13.470	13.489	-2.670	-1.024
12 Road Transportation	**425.536**	**-89.878**	**881.945**	**385.071**	**679.199**	**796.357**	**300.863**	**273.851**	**-162.479**	**190.743**
13 Railroad equipment & transport equip nec.	-0.004	0.076	-0.517	-0.184	0.080	-0.588	-0.271	-1.463	-0.451	-1.195
14 Electricity	**258.366**	**165.571**	**1092.886**	**140.917**	**468.559**	**3032.624**	**739.876**	**2692.603**	**-141.137**	**1097.082**
15 Other industries	54.096	-34.776	146.990	49.734	74.687	98.017	53.641	441.531	68.025	-13.085
16 Construction	-0.580	0.482	-0.389	-4.880	-6.874	4.373	-0.491	1.142	0.815	0.968
17 Water Transport, building and repairs of ships and boats	19.658	-11.332	-39.991	-26.769	29.095	16.865	-25.092	22.077	1.554	-6.767
18 Aircraft& Spacecraft and Air transport	1.867	-3.805	10.651	59.607	24.465	33.840	2.687	-2.576	2.645	7.940
19 Commercial/Institutional	-23.197	4.260	-47.265	-92.012	103.324	92.426	-18.723	0.701	15.271	-15.370

Contd.

	11 Matchinery & Equipment	12 Road Transportation	13 Railroad equipment & transport equip nec.	14 Electricity	15 Other industries	16 Construction	17 Water Transport, building and repairs of ships and boats	18 Aircraft& Spacecraft and Air transport	19 Commercial/Institutional	**TECHNOLOGY CHANGE**
1 Agriculture, hunting, forestry and fishing	-39.244	-21.628	-0.206	-1.112	10.580	-53.088	-0.297	-2.543	-745.643	**0.912**
2 Mining and quarying (energy and non energy)	325.347	689.635	11.835	1267.413	337.114	935.357	141.965	98.977	1304.791	**9553.852**
3 Food products, beverages and tobacco	-2.049	-3.837	0.389	-0.805	-8.640	-14.098	0.212	-1.011	154.211	**599.857**
4 Pulp, paper, paper products, printing and publishing	-182.330	-95.993	-6.061	1.757	-1308.012	-79.312	-2.256	-18.080	-35.708	**-989.790**
5 Coke, refined petroleum & gas	**561.670**	**2920.966**	**22.949**	**1314.826**	**1424.601**	**2235.144**	**561.303**	**488.376**	**6721.590**	**21360.385**
6 Chemical and phamaceuticals	-634.457	174.274	-7.550	35.978	2123.605	-519.046	13.326	-35.547	-508.605	**9089.285**
7 Other non-metallic mineral products	1297.683	426.374	81.828	46.052	-33.232	-4457.895	12.302	56.319	-1557.699	**-3936.888**
8 Iron & steel	**11068.715**	**3167.933**	**945.979**	**470.708**	**1034.284**	**9716.028**	**3355.668**	**-256.391**	**-6831.775**	**54357.417**
9 Non-ferrous metals	616.279	276.575	8.467	25.723	-37.067	484.219	20.114	-2.059	-79.442	**1761.287**
10 Fabricated metal products, except machinery & equipment	4.053	-0.586	0.115	0.754	-0.113	32.702	0.842	-0.105	-7.220	**31.112**
11 Matchinery & Equipment	387.164	-22.472	0.725	87.357	-18.307	-132.273	-19.193	2.226	-198.005	**170.363**
12 Road Transportation	**-751.387**	**15111.346**	**52.499**	**645.555**	**-251.615**	**1427.725**	**135.638**	**-872.516**	**-1266.622**	**17911.831**
13 Railroad equipment & transport equip nec.	5.451	-92.334	73.535	-0.178	-5.356	-6.145	-0.702	-0.378	-28.078	**-58.701**
14 Electricity	**4258.043**	**491.859**	**115.763**	**493.614**	**2308.310**	**1728.739**	**679.941**	**-92.068**	**-4501.886**	**15029.661**
15 Other industries	-0.838	266.121	12.928	126.607	1633.760	24.562	69.400	-33.701	-2268.796	**768.902**
16 Construction	3.606	-10.261	-0.360	-16.454	-0.006	-3.757	0.709	-0.485	-92.498	**-124.940**
17 Water Transport, building and repairs of ships and boats	-160.305	-124.935	-2.082	65.278	111.892	-125.761	2239.835	-28.502	-262.016	**1692.702**
18 Aircraft& Spacecraft and Air transport	-83.334	-282.716	2.061	12.439	-51.407	-29.841	-0.934	563.022	1413.724	**1680.334**
19 Commercial/Institutional	49.567	-54.604	10.972	-15.699	-108.949	-214.157	11.904	-20.847	-3253.571	**-3575.969**

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