PROJECTION OF THE CHANGE IN TECHNOLOGY AND ITS IMPLICATION ON ENVIRONMENTAL EMISSIONS IN JAPAN

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Abstract: The production and use of materials and energy induce many environmental problems not only now but also in the future. The techniques in production change over time thereby changing emission patterns as well. This paper investigates the implication of the projection of the changes in construction technology of road construction categories on carbon pollutants in Japan. The hybrid rectangular input-output (HRIO) methodology is employed to overcome the shortcomings of the commodity by commodity framework. The paper, further, analyzes sources of inter-temporal technological changes affecting carbon emissions through the projection of the 1975 commodity by industry matrix to 1995 using the biproportional technique coupled with the structural decomposition analysis (SDA). It was shown that fabrication effects in cement and cement products, transportation services and metal products contribute more to the changes in non-construction technology, which affects carbon emissions.

Key Words: Hybrid Rectangular Input Output, CO_2, SDA and Biproportional Method

1. INTRODUCTION

Construction of infrastructure facilities like road construction is important in the growth of a nation because it helps promote accessibility and faster movement of goods and persons. There are, however, externalities that we need to consider in the construction of such facilities. Sources of change in carbon emission intensities induced by road construction are very important to be able to come up with policy decisions, which can reduce the emissions from major contributors. Production processes of materials used in road construction also contribute to carbon emissions. These processes including the materials used in construction are part of what is defined as technology. Changes in technology affect in part or in whole the carbon dioxide emissions from any industry. The conventional Input-Output model has been employed to estimate environmental loads due to the production processes of the entire economic system. Previous studies (Gale, 1995; Weir, 1998; Piantanakulchai, *et al.,* 1999) estimated carbon emissions and sources of change by using the static input-output model using the commodity by commodity framework. These studies are limited to the calculation of the environmental impacts of a given final demand. They failed to identify the important interconnections between the complex interactions of the environment and the economy as well as the secondary production in the economy. Hence, this paper tries to overcome these shortcomings by using the hybrid rectangular input-output (HRIO) model. The paper analyzes sources of inter-temporal technological changes affecting carbon emissions through the projection of the 1975 commodity by industry matrix to 1995 using the biproportional technique coupled with the structural decomposition analysis (SDA). Moreover, the components of technological changes are further decomposed to be able to distinguish the nature of these changes, which affect carbon emissions.

Several techniques are available to adjust technological coefficients from input-output data. Lecomber (1975) summarizes several techniques available in updating IO coefficients. The techniques mentioned had different advantages and disadvantages namely the sign problem (Friedlander method), computational problems (Matuszewski's linear programming method). Among the methods compared the "comparative simplicity of RAS over other methods that preserve signs is an overriding asset". Toh (1998) attempts to improve the interpretation and usefulness of the RAS method by interpreting it as statistical estimates. The RAS technique in these studies was used for the basic Leontief table. St. Louis (1989) tests several semi-survey techniques using the rectangular IO model and the basic IO model and he concludes that the "rectangular RAS compared favorably with the Leontief RAS". Mesnard (1990, 1997) introduces the biproportional filter that compares the column and row coefficient variation simultaneously, independently of the fixed technical coefficient (Leontief's) mechanism or fixed allocation coefficients (Ghosh's) mechanism. Andréosso-O'Callaghan and Yue (2000) use the biproportional method to analyze the structural change in the Chinese manufacturing industry. The RAS technique is a biproportional method, in which an original matrix is adjusted/projected with respect to the row and column margins of a future matrix. This paper will use the biproportional method to get the 1995 input and output coefficients of the rectangular model based on the 1975 coefficients. Dietzenbacher and Hoekstra (2000) analyze the effects of technological change and trade on the sectoral outputs in the Netherlands using the RAS structural decomposition approach. Implications of the projected and decomposed technological coefficients on carbon emissions are presented.

The paper is organized as follows. Following this introduction, the framework of the model is discussed. In this section the formulation of the carbon emission model is discussed, the structural decomposition of the formulated model is then presented. After the SDA, the Biproportional Method used in the study is presented. In section 2.4, the decomposition of the biproportional multipliers is described. In section 3, an empirical example that makes use of the information from the Japanese rectangular IO tables is shown. Finally, section 4 completes the paper.

2 FRAMEWORK OF THE STUDY

2.1 Carbon Dioxide Emission Model

The formulation of the carbon emission intensity model is based on the rectangular hybrid framework (Kagawa and Inamura, 2000; Gerilla, *et al.*, 2000). The rectangular hybrid framework makes use of the commodity by industry model, which addresses the problem of secondary production of industries. It also identifies the interdependencies of decomposed economic subsystems whether it is forward, or backward linkages by means of the hierarchical decomposition of the industries (Gerilla, *et al.*, 2000). The economy in this model is subdivided into 3 subsystems namely: the carbon producing industries (es), the non-construction industries (nc) and the construction industries, (cs). The comparison of the emission structure among carbon-producing industries, non-construction industries and construction industries can be explained using the decomposition of the matrices. The decomposition is shown below:

$$\underbrace{\begin{array}{c} \\ es \\ nc \\ cs \end{array}\begin{array}{c} \begin{array}{ccc} es & nc & cs \end{array} \\ \left[\begin{array}{c:c:c} B_{11} & B_{12} & B_{13} \\ \hdashline B_{21} & B_{22} & B_{23} \\ \hdashline B_{31} & B_{32} & B_{33} \end{array}\right] \end{array}}_{B_h} = \underbrace{\left[\begin{array}{c:c:c} B_{11} & B_{12} & B_{13} \\ \hdashline B_{21} & O & O \\ \hdashline B_{31} & O & O \end{array}\right]}_{B_{es}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & B_{22} & B_{23} \\ \hdashline O & B_{32} & O \end{array}\right]}_{B_{nc}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & O & O \\ \hdashline O & O & B_{33} \end{array}\right]}_{B_{cs}} \quad (1)$$

$$\underbrace{\begin{array}{c} \\ es \\ nc \\ cs \end{array}\begin{array}{c} \begin{array}{ccc} es & nc & cs \end{array} \\ \left[\begin{array}{c:c:c} C^{-1}_{11} & C^{-1}_{12} & C^{-1}_{13} \\ \hdashline C^{-1}_{21} & C^{-1}_{22} & C^{-1}_{23} \\ \hdashline C^{-1}_{31} & C^{-1}_{32} & C^{-1}_{33} \end{array}\right] \end{array}}_{C^{-1}_h} = \underbrace{\left[\begin{array}{c:c:c} C^{-1}_{11} & C^{-1}_{12} & C^{-1}_{13} \\ \hdashline C^{-1}_{21} & O & O \\ \hdashline C^{-1}_{31} & O & O \end{array}\right]}_{C^{-1}_{es}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & C^{-1}_{22} & C^{-1}_{23} \\ \hdashline O & C^{-1}_{32} & O \end{array}\right]}_{C^{-1}_{nc}} + \underbrace{\left[\begin{array}{c:c:c} O & O & O \\ \hdashline O & O & O \\ \hdashline O & O & C^{-1}_{33} \end{array}\right]}_{C^{-1}_{cs}} \quad (2)$$

B_{es} is a block matrix consisting of the input coefficient sub-matrices of carbon-producing industries, B_{nc} is a block matrix of input coefficient sub-matrices of non-construction industries and B_{cs} is a block matrix consisting of input coefficient sub-matrices of construction industries. Similarly, C^{-1}_{es}, is a block matrix consisting of the market share sub-matrices relating to the carbon-producing industry. C^{-1}_{nc} is a block matrix consisting of the market share sub-matrices relating to the non-construction industry. Furthermore, C^{-1}_{cs} is a block matrix consisting of the market share sub-matrices relating to the construction industry. This decomposition shows the interdependency of the three subsystems in the economy. The units of elements of the block matrices are in hybrid units meaning that the carbon producing industries units are in ton-carbon (ton-C) while the other sectors, non-construction and construction sectors, retain their monetary units which are in million yen (MY).

The carbon dioxide emission model used in the study is shown in equation (3)

$$CO_{es} = E_{gnc} * \left(I - B_{nc} C^{-1}_{nc}\right)^{-1} f^{c}_{nc} \quad (3)$$

where:

CO_{es} = vector of total carbon emission intensity from the carbon producing industries induced by the non-construction sector for the production of a construction commodity;

E_{gnc} = matrix of carbon emission structure induced by the non-construction industry;

B_{nc} = input coefficient matrix of the non-construction industry;

C^{-1}_{nc} = non-construction market share matrix of output coefficients;

f^{c}_{nc} = vector of non-construction industry requirements of a construction commodity c;

The non-construction carbon emission structure, E_{gnc}, implies the different linkages of the 3 decomposed subsystems relating to the non-construction industry. This was taken from the decomposition of the industrial production function of the rectangular model (see Gerilla, *et al.*, 2000). We have E_g as the matrix of total carbon emission coefficient of industries induced by the non-construction sector for the production of final demand.

$$E_g = (C^{-1} + C^{-1}L_0B_{es}C^{-1})(I + L_2B_{cs}C_a^{-1})(I + L_3B_{nc}C_{cs}^{-1}) \tag{4}$$

where:

$L_0 = (I - BC^{-1})^{-1}$ $\quad$ $L_3 = (I - B_{nc}C_a^{-1})^{-1}$ $\quad$ $B_a = B_{nc} + B_{cs}$

$L_2 = (I - B_aC_a^{-1})^{-1}$ $\quad$ $C^{-1}{}_a = C^{-1}{}_{nc} + C^{-1}{}_{cs}$

Equation (4) can be presented in matrix form as follows:

$$E_g = \begin{bmatrix} E_{g11} & E_{g12} & E_{g13} \\ E_{g21} & E_{g22} & E_{g23} \\ E_{g31} & E_{g32} & E_{g33} \end{bmatrix} \tag{5}$$

where:

E_{g11} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;
E_{g12} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the non-construction sector;
E_{g13} = carbon producing industry output submatrix of carbon producing industries induced by the final demand of the construction sector;
E_{g21} = non-construction output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;
E_{g22} = non-construction output submatrix of carbon producing industries induced by the final demand of the non-construction sector;
E_{g23} = non-construction output submatrix of carbon producing industries induced by the final demand of the construction sector;
E_{g31} = construction output submatrix of carbon producing industries induced by the final demand of the carbon-producing sector;
E_{g32} = construction output submatrix of carbon producing industries induced by the final demand of the non-construction sector;
E_{g33} = construction output submatrix of carbon producing industries induced by the final demand of the construction sector;

The carbon emission coefficient vector of carbon producing industries is given in the matrix below:

$$E_{ge} = [E_{g11} \,\vdots\, E_{g12} \,\vdots\, E_{g13}] \tag{6}$$

E_{ge} is defined as the direct and indirect emission output acquired as a result of the production processes of the carbon producing sectors, non-construction and the construction sectors. To be able to get the direct and indirect emission output discharged in the processes of the non-construction industry, we can decompose equation (6) to equation (7) as shown below:

$$E_{gnc} = [\, O \,\vdots\, E_{g12} \,\vdots\, O \,] \tag{7}$$

The final demand, f_{nc}^{c}, is actually a final demand converter (Piantanakulchai, *et al.,* 1999) wherein the non-construction input transactions of a road construction commodity is used. This study uses all construction commodities relating to road construction namely: pavement (local and national), bridge (local and national), improvement, repair, local road, earthworks and other construction works.

2.2 Structural Decomposition Analysis

The total change in carbon emissions intensities is decomposed into effects caused by the changes in the emission structure of carbon producing sectors, E_{gnc}, changes in non-construction technology, $(I - B_{nc}C_{nc}^{-1})^{-1}$ as well as changes in the construction technology, f_{nc}^{c} of the road construction sector. If we let $L_{nc} = (I - B_{nc}C_{nc}^{-1})^{-1}$ and using equation (3), we can carry out its decomposition over time by

$$\Delta CO_{es} = E_{gnc1}L_{nc1}f_{nc1}^{c} - E_{gnc0}L_{nc0}f_{nc0}^{c} \quad (8)$$

The subscripts 1 and 0 denote the future time t1 and base time t0, respectively. Equation (8) can be transformed into six different types of decomposition forms and the average effects of the changes in the carbon emission structure are shown in equation (9).

$$(1/6)\cdot\left[2\cdot\left(\Delta E_{gnc}L_{nc1}f_{nc1}^{c}\right)+2\cdot\left(\Delta E_{gnc}L_{nc0}f_{nc0}^{c}\right)+\Delta E_{gnc}L_{nc1}f_{nc0}^{c}+\Delta E_{gnc}L_{nc0}f_{nc1}^{c})\right] \quad (9)$$

Moreover, equation (10) estimates the average effects of changes in construction technology. The changes in construction technology refer to the changes in the intermediate non-construction input requirements of a construction commodity.

$$(1/6)\cdot\left\{2\left(E_{gnc0}L_{nc0}\Delta f_{nc}^{c}\right)+2\left(E_{gnc1}L_{nc1}\Delta f_{nc}^{c}\right)+E_{gnc1}L_{nc0}\Delta f_{nc}^{c}+E_{gnc0}L_{nc1}\Delta f_{nc}^{c}\right\} \quad (10)$$

The average effects of the changes in non-construction technology are displayed in equation (11)

$$(1/6)\cdot\left[2\cdot\left(E_{gnc0}\Delta L_{nc}f_{nc0}^{c}\right)+2\cdot\left(E_{gnc1}\Delta L_{nc}f_{nc1}^{c}\right)+E_{gnc0}\Delta L_{nc}f_{nc1}^{c}+E_{gnc1}\Delta L_{nc}f_{nc0}^{c}\right] \quad (11)$$

Moreover, the effects of changes in the non-construction technology, ΔL_{nc}, can be further subdivided into the effects of changes in the input structure in the non-construction industry, ΔB_{nc} and into the effects of the changes in the product mix of the non-construction industry, ΔC_{nc}^{-1}.

$$\begin{aligned}\Delta L_{nc} &= \left[\left(I-B_{nc}C_{nc}^{-1}\right)^{-1}\right]_{1}-\left[\left(I-B_{nc}C_{nc}^{-1}\right)^{-1}\right]_{0}\\ &= L_{nc0}\Delta B_{nc}C_{nc0}^{-1}L_{nc1}+L_{nc0}B_{nc1}\Delta C_{nc}^{-1}L_{nc1}\\ &= L_{nc0}B_{nc1}\Delta C_{nc0}^{-1}L_{nc1}+L_{nc0}\Delta B_{nc1}C_{nc1}^{-1}L_{nc1}\end{aligned} \quad (12)$$

The average effects of the non-construction technology can be further decomposed into effects of the input structure and the average effects of product mix. The formulation of the effects of changes in the input structure is shown in equation (13).

$$(1/12)\cdot\{2\cdot(E_{gnc0}L_{nc0}\Delta B_{nc}C_{nc0}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc0}L_{nc0}\Delta B_{nc}C_{nc1}L_{nc1}f^{c}_{nc1})+ 2\cdot(E_{gnc1}L_{nc0}\Delta B_{nc}C_{nc0}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc1}L_{nc0}\Delta B_{nc}C_{nc1}L_{nc1}f^{c}_{nc1})+ E_{gnc1}L_{nc0}\Delta B_{nc}C_{nc1}L_{nc1}f^{c}_{nc0}+E_{gnc1}L_{nc0}\Delta B_{nc}C_{nc0}L_{nc1}f^{c}_{nc0}+ E_{gnc0}L_{nc0}\Delta B_{nc}C_{nc0}L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}\Delta B_{nc}C_{nc1}L_{nc1}f^{c}_{nc0}\} \tag{13}$$

The effects of changes in product mix are presented in equation (14).

$$(1/12)\cdot\{2\cdot(E_{gnc0}L_{nc0}B_{nc1}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc0}L_{nc0}B_{nc0}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc1})+ 2\cdot(E_{gnc1}L_{nc0}B_{nc1}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc1}L_{nc0}B_{nc0}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc1})+ E_{gnc1}L_{nc0}B_{nc1}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc0}+E_{gnc1}L_{nc0}B_{nc0}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc0}+ E_{gnc0}L_{nc0}B_{nc1}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}B_{nc0}\Delta C^{-1}_{nc}L_{nc1}f^{c}_{nc0}\} \tag{14}$$

2.3 Biproportional Method

The biproportional method allows the transformation of an initial matrix of technological coefficients by a series of iterations to get an updated/projected matrix wherein the errors between the two matrices are a minimum. For the rectangular matrix, both the B and C coefficient matrices are updated. The method is summarized as follows. Let V be the original matrix in a given time period and K, the target or final matrix that can be observed. The biproportional method produces a projected matrix, V* from matrix V and the row and column margins of K.

$$V^* = \langle\hat{r}\rangle V \langle\hat{s}\rangle \tag{15}$$

such that:

$$\sum_j V_{ij} = k_i = \sum_j V^*_{ij} \qquad \sum_i V_{ij} = k_j = \sum_i V^*_{ij}$$

where $\langle\hat{r}\rangle$ and $\langle\hat{s}\rangle$ are two diagonal matrices and kj and ki are the column and row margins, respectively. In order to calculate V*, it is necessary to calculate the diagonal multipliers $\langle\hat{r}\rangle$ and $\langle\hat{s}\rangle$. An iterative mathematical algorithm for the calculation of biproportionality is shown in equation (16) and equation (17). First, we let $r^0_i = 1$ and solve for s_j that satisfy the constraints above.

$$s_j^{n+1} = \frac{k_j}{\sum_i V_{ij} r_i^n} \tag{16}$$

$$r_i^{n+1} = \frac{k_i}{\sum_j V_{ij} s_j^{n+1}} \tag{17}$$

The n iteration stops when the margins of V* approximate the margins of K. This algorithm is similar to the Furness method in transportation planning. In the study, the industry by commodity matrix is used for the original matrix with the industry output, g_i and commodity outputs, q_j in 1995 for the row and column margins, respectively. The same multipliers are used to update the output coefficient, C while the input coefficient, B is calculated from the projection of the technical coefficients A and C, since no use matrices, U are available in Japan. Biproportionality has a multiplicative form where all the terms in the original matrix, V should be positive or zero.

There are several measures to compare the two matrices (Miller and Blair, 1985). One measure is to average the elements in the errors, e_{ij} between V* and K called the mean absolute deviation. The formula is shown below:

$$MAD=\left(\frac{1}{m^2}\right)\sum_i\sum_j\left|e_{ij}\right| \tag{18}$$

The variable m stands for the number of sectors/industries in the matrix. The value represents the average amount by which the estimated matrix/coefficient differs from the true matrix/coefficient. Another measure is the distance or norm between the vectors or matrices:

$$\left\|d_i\right\|=\sqrt{\sum_j\left(v_{ij}^*-k_{ij}\right)^2} \tag{19}$$

The norm of the matrix measures the structural changes between the two time periods selected (Mesnard, 1990, 1997; Andréosso-O'Callaghan and Yue, 2000).

2.4 The Decomposition of the Biproportional Multipliers

The r_i and s_j multipliers are interpreted as the substitution factors and fabrication effects, respectively (Miller and Blair (1985), Toh (1998), Dietzenbacher and Hoekstra (2000)). The row specific changes, in the coefficient matrix or substitution effects measure the changes or replacement of the inputs, over time while the column specific changes measure the changes in the absorption of intermediate inputs of each industry, over time. Applying the non-construction industries' direct requirements matrix, B_{nc} to the biproportional equation given in equation (15), we have:

$$B_{nc}{}^*=\langle\hat{r}\rangle B_{nc}\langle\hat{s}\rangle \tag{20}$$

and the non-construction market share matrix, C_{nc}^{-1} is also applied to the biproportional equation to get:

$$C_{nc}^{-1*}=\langle\hat{r}\rangle C_{nc}^{-1}\langle\hat{s}\rangle \tag{21}$$

The decomposition of the input structure and product mix changes in equations (13) and (14) can be further decomposed into substitution effects and fabrication effects. So taking equation (22), we have the changes in the input structure, the non-construction direct requirements matrix in the base year is deducted from the projected matrix. Since the projected matrix can not fully describe the changes that occur, an error term is added to the projected matrix to signify the full future year coefficient.

$$\begin{aligned}\Delta B_{nc} &= B^{*}_{nc} - B_{nc} \\ &= \hat{r}B_{nc}\hat{s} + \varepsilon - B_{nc} \\ &= \hat{r}B_{nc}\hat{s} + \varepsilon - \hat{r}_0 B_{nc}\hat{s}_0\end{aligned} \tag{22}$$

Using the same decomposition technique as in the section 2.2, we can decompose the changes in input structure into changes with respect to changes in substitution and changes in intermediate input intensity. The decomposition is shown in equation (23).

$$\begin{aligned}\Delta B_{nc} &= \Delta\hat{r}_{nc} B_{nc}\hat{s}_{nc} + \hat{r}_{nc0} B_{nc}\Delta\hat{s}_{nc} \\ &= \hat{r}_{nc} B_{nc}\Delta\hat{s}_{nc} + \Delta\hat{r}_{nc} B_{nc}\hat{s}_{nc0}\end{aligned} \tag{23}$$

Taking the average effects, yields equation (24). Similarly, we can get the decomposed effects in the changes in product mix as shown in equation (25). Note that the error terms denotes the cell specific changes (Dietzenbacher and Hoekstra (2000)).

$$\Delta B_{nc} = 1/2(\hat{r}_{nc} - I)B_{nc}(\hat{s}_{nc} + I) + 1/2(\hat{r}_{nc} + I)B_{nc}(\hat{s}_{nc} - I) + \varepsilon \tag{24}$$

$$\Delta C^{-1}{}_{nc} = 1/2(\hat{r}_{nc} - I)C^{-1}{}_{nc}(\hat{s}_{nc} + I) + 1/2(\hat{r}_{nc} + I)C^{-1}{}_{nc}(\hat{s}_{nc} - I) + \varepsilon \tag{25}$$

The error term, however, is negligible that we can cancel it out from the decomposed equation to only reflect the substitution effects and the fabrication effects. The average decomposition of the changes in input structure and product mix in (24) and (25) can be substituted in equation (13) and equation (14), respectively. The resulting equations of the decomposed input technology structure changes are decomposed into the changes in carbon emission due to the average effects of changes in substitution (equation 26) and the carbon emission due to the average effects in the changes in fabrication effects (equation 27).

$$\begin{aligned}&(1/24)\cdot\{2\cdot(E_{gnc0}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc0}L_{nc1}f^{c}_{nc1})+ \\ &2\cdot(E_{gnc0}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc1}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc1}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc0}L_{nc1}f^{c}_{nc1})+ \\ &2\cdot(E_{gnc1}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc1}L_{nc1}f^{c}_{nc1})+E_{gnc1}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc1}L_{nc1}f^{c}_{nc0}+ \\ &E_{gnc1}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc0}L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc0}L_{nc1}f^{c}_{nc0}+ \\ &E_{gnc0}L_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)C_{nc1}L_{nc1}f^{c}_{nc0}\}\end{aligned} \tag{26}$$

$$\begin{aligned}&(1/24)\cdot\{2\cdot(E_{gnc0}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc0}L_{nc1}f^{c}_{nc1})+ \\ &2\cdot(E_{gnc0}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc1}L_{nc1}f^{c}_{nc1})+2\cdot(E_{gnc1}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc0}L_{nc1}f^{c}_{nc1})+ \\ &2\cdot(E_{gnc1}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc1}L_{nc1}f^{c}_{nc1})+E_{gnc1}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc1}L_{nc1}f^{c}_{nc0}+ \\ &E_{gnc1}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc0}L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc0}L_{nc1}f^{c}_{nc0}+ \\ &E_{gnc0}L_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)C_{nc1}L_{nc1}f^{c}_{nc0}\}\end{aligned} \tag{27}$$

The decomposition of the technological product mix changes into the average effects of substitution (equation 28) and average fabrication effects (equation 29) are also presented.

$$
\begin{aligned}
&(1/24)\cdot\Big\{2\cdot\big(E_{gnc0}L_{nc0}B_{nc1}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc1}\big)+\\
&2\cdot\big(E_{gnc0}L_{nc0}B_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc1}\big)+2\cdot\big(E_{gnc1}L_{nc0}B_{nc1}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc1}\big)+\\
&2\cdot\big(E_{gnc1}L_{nc0}B_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc1}\big)+E_{gnc1}L_{nc0}B_{nc1}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc0}+\\
&E_{gnc1}L_{nc0}B_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}B_{nc1}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc0}+\\
&E_{gnc0}L_{nc0}B_{nc0}(\hat{r}B_{nc0}+B_{nc0})(\hat{s}-I)L_{nc1}f^{c}_{nc0}\Big\}
\end{aligned}
\tag{28}
$$

$$
\begin{aligned}
&(1/24)\cdot\Big\{2\cdot\big(E_{gnc0}L_{nc0}B_{nc1}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc1}\big)+\\
&2\cdot\big(E_{gnc0}L_{nc0}B_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc1}\big)+2\cdot\big(E_{gnc1}L_{nc0}B_{nc1}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc1}\big)+\\
&2\cdot\big(E_{gnc1}L_{nc0}B_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc1}\big)+E_{gnc1}L_{nc0}B_{nc1}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc0}+\\
&E_{gnc1}L_{nc0}B_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc0}+E_{gnc0}L_{nc0}B_{nc1}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc0}+\\
&E_{gnc0}L_{nc0}B_{nc0}(\hat{r}B_{nc0}-B_{nc0})(\hat{s}+I)L_{nc1}f^{c}_{nc0}\Big\}
\end{aligned}
\tag{29}
$$

3. APPLICATION AND RESULTS

The 1975 hybrid coefficient matrices for non-construction, B_{nc} and C_{nc} were projected to 1995 using the biproportional method discussed in section 2.3. The monetary terms in 1975 and 1995 were converted to 1985 prices to exclude price components from the analysis of structural change. The sectors in the V matrix for 1975 do not correspond to the basic input-output classification therefore both tables were aggregated into a 60x60 matrix for the analysis years.

Selected values for $\langle\hat{r}\rangle$ and $\langle\hat{s}\rangle$ and the corresponding error measures are shown in Table 1. The results used information on the coefficients from the 1975 IO table and 1975 V matrix and marginal totals from the 1995 IO table and the 1995 V matrix. Table 1 indicates that structural change has occurred during 1975 to 1995 as shown in the difference between the projected coefficient matrices and the target coefficient matrices. The structural changes that happened during the 20-year period are more or less uniform and stable across the sectors.

Moreover, we can see that the highest structural change that occurred is from the organic and inorganic chemicals and transportation services. It can also be seen from Table 1 that fabrication effects is more dominant during the 20 year period compared to substitution effects. The value of the substitution factor which is less than 1 means that there is substitution away from the industry (e.g., Agriculture, Pulp and Paper, etc.). A value of more than 1 means that substitution is toward that sector (e.g., Research, Other personal services, transport vehicles). Decreased fabrication multipliers means a dependence on high technological equipment or more skilled labor. The mean average deviation (MAD) shows the average amount by which an estimated coefficient differs from the true coefficient. It implies that the updated coefficients can relatively estimate the final matrix since the values are small (0.0088, 0.0051,respectively). The carbon emission intensities for each road construction commodity are calculated after the technological coefficients have been updated.

Table 1 Computed r and s factors with the computed norm

	Input Structure			Product Mix		
	Substitution Multipliers	Fabrication Multipliers	$\|d_i\|$	Substitution Multipliers	Fabrication Multipliers	$\|d_i\|$
Agriculture for crops	0.30	4.03	0.19	1.80	1.39	2.42
Livestock and sericulture	0.50	1.81	0.10	0.81	1.05	0.15
Agricultural services	0.50	1.41	0.05	1.40	0.71	0.24
Forestry	0.10	22.38	0.26	0.63	1.56	0.04
Fisheries	0.70	0.92	0.07	0.84	1.22	0.06
Iron ore mining, Metallic Ores	1.70	0.17	0.05	0.97	1.00	0.00
Timber and wooden products	0.50	1.67	0.19	1.01	0.99	0.04
Furniture and fixtures	0.60	1.19	0.02	1.04	0.96	0.08
Pulp and paper products	0.20	6.68	0.31	1.04	1.18	0.52
Rubber and rubber products	1.50	0.04	0.07	1.05	1.01	0.20
Organic and inorganic chemicals	1.00	1.80	0.57	1.18	1.02	0.61
Resins and chemical fiber	1.20	0.69	0.12	1.29	0.79	0.26
Final chemical products	1.20	0.63	0.08	0.97	0.98	0.11
Cement and cement products	0.70	0.32	0.12	0.99	1.00	0.05
Pig iron and crude steel	1.00	0.92	0.06	0.35	2.96	1.73
Steels and steel products	0.80	0.79	0.15	0.99	1.20	0.86
Non-ferrous metals and products	1.90	0.35	0.20	4.09	0.18	0.10
Metal products for construction	1.00	0.70	0.10	0.45	2.17	0.22
Industrial machinery	0.40	1.09	0.09	0.41	2.33	0.27
Electrical and communication equipment	0.90	1.22	0.10	1.18	1.12	0.77
Transport vehicles and its repair	1.70	1.43	0.24	1.10	1.20	0.83
Scientific instruments	0.60	1.12	0.02	0.98	1.03	0.21
Other manufacturing products	0.40	0.68	0.05	1.88	0.51	0.28
Water supply	3.00	0.37	0.09	1.00	1.00	0.00
Waste disposal services	2.30	0.52	0.01	1.01	1.00	0.01
Wholesale and retail trade	1.00	0.66	0.26	0.75	1.10	0.10
Financial service and insurance	0.80	1.31	0.39	1.00	1.00	0.00
Real estate agency and house rent	7.10	5.19	0.07	1.00	1.00	0.00
Transportation, packing and its services	0.60	1.08	0.43	0.94	1.07	0.02
Telecommunication	1.00	1.40	0.07	1.00	1.00	0.00
Education	3.10	0.63	0.01	1.00	1.00	0.00
Research	49.40	0.72	0.10	1.00	1.00	0.00
Medical service and health	3.20	0.95	0.03	1.00	1.00	0.01
Other public services	0.70	2.03	0.02	1.00	1.12	0.23
Advertising, information and other business services	1.50	1.15	0.17	1.01	1.02	0.06
Goods rental, leasing and car rental	7.30	1.05	0.07	0.97	1.08	0.10
Amusement and recreation facilities	2.70	0.75	0.02	1.03	0.98	0.03
Broadcasting	0.70	0.76	0.03	1.00	1.00	0.01
Other personal services	220.80	0.63	0.06	1.05	0.96	0.23
Mean Average Deviation (MAD)	0.0088			0.0051		

The following figure shows the carbon emission intensities for each road construction category in 1975 and 1995. Carbon emission from the local pavement construction increased by 45% from 1975-1995 while emissions from bridge construction decreased by 6% during the same period. It is also seen that emissions due to improvement and local bridge construction had very minimal change over time. Furthermore, the highest carbon intensities come from bridge construction both national and local construction, and other construction. The sources of the major contributors of the changes in emission levels are discussed in the next table.

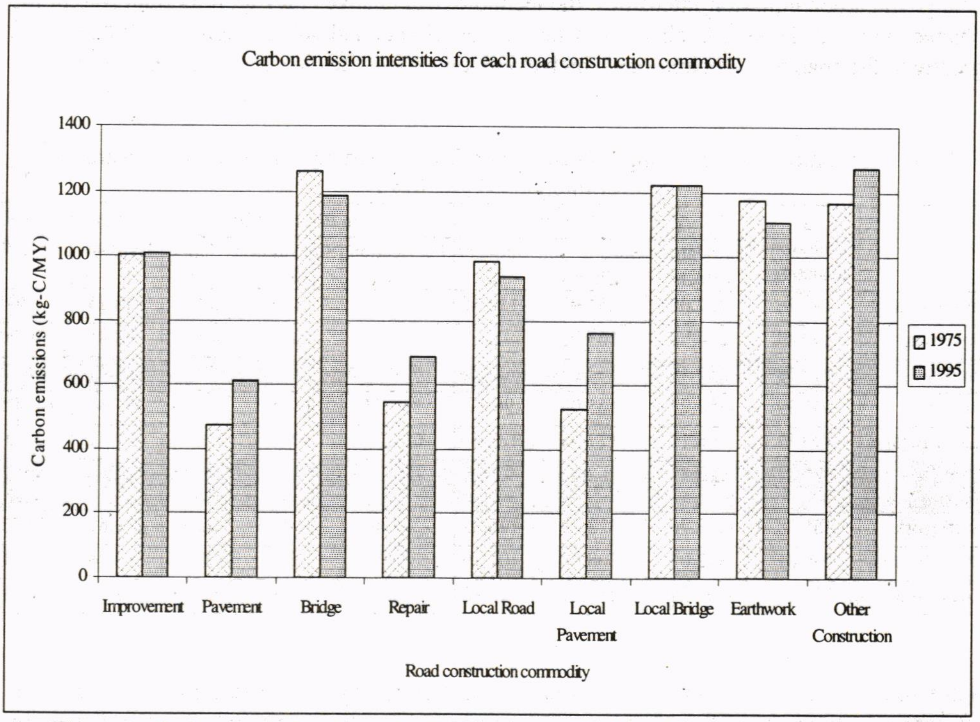

Figure 1. Carbon emission intensity in 1975 and 1995 for different road construction commodities

Table 2 presents the sources of changes in carbon intensity for each road construction category. For the twenty-year period, only slight changes in carbon emissions are seen for all construction commodities. We notice that fabrication effects in the input structure contributed to a decrease in emission intensity. It can be implied that manufacturing of intermediate inputs have improved tremendously during the time period. It can be further suggested that labor skills have also improved thereby contributing to negative effects in fabrication technology. For the changes in product mix, however, the substitution effects have positive effects to the change in carbon emissions.

The shaded portion in Table 2 highlights the road construction commodity, which gives out the highest increase and largest decrease in carbon emission intensity. It can be seen that for the local pavement construction, final demand changes or road construction technology is the reason for the increase in carbon emission change. It is also interesting to note that pavement and local pavement construction have low carbon emission intensities but their total change in carbon emission intensities are the highest. For bridge construction, however, the major sources of the change are the fabrication effects in the input structure and the change in the emission structure. It is noticeable that eventhough the bridge construction gives the highest carbon intensity among all road construction commodities, total change in carbon emission decreased very much.

Furthermore, for improvement and local bridge construction, where there is very minimal change in carbon emission intensities, the technological changes play an important role in the change. Table 2 shows that changes in fabrication effects and substitution effects contribute greatly to the changes in technology which eventually affect the change in carbon emissions.

Table 2 Decomposition of changes in carbon emission intensity for each road construction commodity (kg-C/MY)

	Δ Emission Structure	Δ in Input Structure			Δ in Product Mix			Δ Final Demand	Total CO_2 Δ
		Fabrication Effects	Substitution Effects	Sub-Total	Fabrication Effects	Substitution Effects	Sub-Total		
Improvement	-492.76	-367.08	254.93	-112.16	-125.48	184.95	59.47	548.75	3.30
Pavement	-209.49	-254.82	163.08	-91.74	-65.16	108.13	42.98	398.45	140.20
Bridge	-412.38	-287.49	162.23	-125.27	-671.37	791.76	120.39	335.43	-81.82
Repair	-197.39	-259.25	163.08	-96.17	-197.77	253.02	55.24	383.37	145.05
Local Bridge	-400.57	-305.12	177.45	-127.66	-687.35	807.95	120.59	401.65	-5.99
Local pavement	-271.84	-280.39	182.87	-97.52	-125.74	175.42	49.66	560.42	240.73
Earthwork	-466.88	-443.76	323.45	-120.32	-247.49	310.35	62.87	459.81	-64.53
Other Works	-790.81	-312.07	208.88	-103.19	25.01	95.64	120.66	897.74	124.40
Local Road	-395.89	-400.24	283.31	-116.93	-136.11	199.68	63.57	397.45	-51.81

Since bridge construction and local pavement construction have interesting results, we delve into the selected intermediate inputs of these commodities that contributed to the change in emission intensities. The next two tables show the effects that contributed to the major increase or decrease in carbon emission.

Table 3 presents the carbon emission change for local pavement construction based on technological changes. Only a selected number of intermediate inputs are presented. This selection is based on the highest rank of decrease or increase in the total carbon emission. If we focus on the fabrication effects and substitution effects, we see that the substitution effects of changes in product mix give the highest changes. The negative effects in the fabrication technology for the input structure and product mix changes are more dominant in cement and cement products, metal products for construction and transportation, packing and its services. This shows that during the twenty-year period, improvement in the technology of manufacturing increased very much for cement and cement product eventhough it is one contributor to the increase in carbon emissions during this period.

For final chemical products and organic and inorganic chemicals, the fabrication and substitution effects of product mix are a minimum.

Table 3 Carbon emission change from Local pavement construction due to technological changes (kg-C/MY)

	Input Structure		Product Mix	
	Fabrication effects	Substitution effects	Fabrication effects	Substitution effects
Non-ferrous metals and products	11.75	-8.89	77.55	-72.15
Steels and steel products	2.07	-2.73	-28.30	33.50
Transport vehicles and its repair	-0.49	0.37	-0.20	0.28
Metal products for construction	-2.36	-8.83	-176.70	194.12
Final chemical products	-2.70	0.85	0.04	0.00
Industrial machinery	-3.22	1.95	-6.76	7.31
Organic and inorganic chemicals	-6.19	5.76	0.87	-0.97
Wholesale and retail trade	-17.60	4.26	-1.45	13.75
Transportation, packing and its services	-52.20	22.61	-1.68	2.76
Cement and cement products	-55.58	59.38	-9.10	15.85

Table 4 shows the technological changes in bridge construction, similar to the local pavement construction, the carbon dioxide changes due to fabrication and substitution effects due to input structure are its more important contributors. Similar to Table 3, we see in Table 4 that manufacturing technology improved in cement and cement products, transportation services and wholesale trade. It is noted that for steel and steel products, substitution effects instead of fabrication effects is the main reason for the improvement in the input structure technology.

Table 4 Carbon emission change from Bridge construction due to technological changes (kg-C/MY)

	Input Structure		Product Mix	
	Fabrication effects	Substitution effects	Fabrication effects	Substitution effects
Cement and cement products	-76.23	61.77	-9.47	16.50
Steels and steel products	13.49	-19.89	-210.08	248.73
Non-ferrous metals and products	12.81	-9.46	82.52	-76.77
Metal products for construction	-12.73	-25.74	-546.20	600.03
Industrial machinery	-2.95	2.25	-7.81	8.43
Final chemical products	-3.11	2.41	0.10	0.01
Transport vehicles and its repair	-0.45	0.38	-0.20	0.28
Transportation, packing and its services	-33.48	15.04	-1.15	1.88
Organic and inorganic chemicals	-5.37	5.23	0.79	-0.89
Wholesale and retail trade	-16.04	3.69	-1.26	11.91

4. CONCLUSION

The biproportional method used is a way to determine the structural changes in the economy. The distance between the new projected matrix and the target matrix allows us to measure the extent of the structural change between the two periods. The results of projection of the 1995 coefficients of the HRIO from the 1975 matrices fitted with the observed 1995 margins were accurate. It was seen that for the 20 year time period that the changes that took place were more or less uniform for the non-construction industry. There were no dominant or less important industries that were responsible for the evolution of the industrial changes.

The decomposition of technology into the substitution and fabrication effects identifies the advances that have been made in the road construction industry. Although final demand effects contribute greatly to the change in carbon emission levels, technological changes also are important. It was shown that fabrication effects contribute more to the changes in technology. It was also seen that bridge construction had the largest carbon emission intensity but gave the largest decrease in the change in emissions from 1975 to 1995.

The major contributors to the increase in carbon emissions in bridge construction and local pavement construction are cement, steel and metal products for construction. Fabrication effects or high dependence on high technological capital equipment basically affects these inputs, except for steel. From 1975-1995, the evolution of technology contributed to the decrease in emission levels but offset by final demand.

REFERENCES

Andréosso-O'Callaghan, B. and Yue, G. (2000) An Analysis of Structural Change in China using Biproportional Methods, **Economic Systems Research Vol. 12, No. 1**, 99-111.

Bullard, C. and Herendeen, R. A., (1975) The energy cost of goods and services, **Energy Policy**, 268-278.

Dietzenbacher, E. and Hoekstra, R. (2000) The RAS Structural Decomposition Approach. –, **Presented in the 13th International Input-Output Conference**, Macerata, Italy, 21-25, August 2000.

Environmental Agency of Japan (1997) Carbon dioxide emission intensity based on the Input-Output Analysis, CGER-Report No. CGER-D016-97, Japan.

Fujimagari, D., (1989) The Sources of Change in Canadian Industry Output, **Economic Systems Research Vol.1 No.2**, 187-201.

Gale, L., IV, (1995) Trade Liberalization and Pollution: An Input-Output Study of Carbon Dioxide Emissions in Mexico, **Economic Systems Research Vol. 7, No. 3**, 309-320.

Gerilla, G., Inamura, H. and Takeyama, Y. (2000) Environmental Impacts of the Building and Road Construction Industry in Japan, **Proceedings of the International Symposium on Lowland Technology**, Saga, Japan, 4-6, October 2000.

Gerilla, G., Kagawa, S. and Inamura, H. (2000) Environmental Effects due to Changes in Construction Technology, **11th Pan Pacific Association of Input-Output Studies Conference Reports**, Sendai, Japan, 3-4, November 2000.

Gerilla, G., Kagawa, S. and Inamura, H. (2001) A Study on Environmental Effects Due to Historical Changes in Technology, To be presented at the 9th World Conference on Transportation Research, Seoul, Korea, 22-26, July 2001.

Kagawa, S. and H. Inamura, (2000) The Structural Decomposition of Energy Consumption Based on a Hybrid Rectangular Input-Output Framework – Japan's Case –, **Presented in the 13th International Input-Output Conference**, Macerata, Italy, 21-25, August 2000.

Lecomber, J.R.C. (1975) A Critique of Methods of Adjusting, Updating and Projecting Matrices, In R.I.G. Allen and W.F. Gossling (eds) **Estimating and Projecting Input-Output Coefficients**, pp. 1-25.

Leontief, W. (1970) Environmental repercussions and the economic structure: An input-output approach, **The Review of Economics and Statistics, Vol. 52**, 3.

Mesnard, L. de (1997) A Biproportional Filter to Compare Technical and Allocation Coefficient Variations, **Journal of Regional Science, Vol. 37, No. 4**, 541-564.

Mesnard, L. de (1990) Biproportional Method for Analysing Interindustry Dynamics: the Case of France, **Journal of Regional Science, Vol. 37, No. 4**, 541-564.

Miller, R. E. and Blair, P.D. (1985) **Input-Output Analysis.** Prentice Hall, Inc, Englewood Cliffs, New Jersey.

Piantanakulchai, M., Inamura, H., and Takeyama, Y. (1999) A Life Cycle Inventory Analysis of Carbon-Dioxide for a Highway Construction Project Using Input-Output Scheme: A Case Study of the Tohoku Expressway Construction Works, **Journal of Infrastructure Planning and Management of Japan Society of Civil Engineers Vol. 16,** 411-418.

Piantanakulchai, M. and Inamura, H. (1999) The Decomposition for the Sources of Changes in Carbon Emission Intensities: A Case Study of Carbon Emissions from Road Construction Work in Japan during 1975-1990, **Journal of the East Asia Society for Transportation Studies Vol. 3 No. 1,** 9-18.

St. Louis, L.V. (1989) Empirical Tests of Some Semi-Survey Update Procedures Applied to Rectangular Input-Output Tables, **Journal of Regional Science, Vol. 29, No.3**, 373-385

Sonis, M. and Hewings, G.J.D. (1990) The 'Matrioshka Principle' in the Hierarchical Decomposition of Multi-Regional Social Accounting Systems, In: L. Anselin & M. Madden (eds) **New Directions in Regional Analysis: Integrated and Multi-regional Approaches** (London, Pinter), pp. 101-111.

Toh, M. (1998) The RAS Approach in Updating Input-Output Matrices: An Instrumental Variable Interpretation and Analysis of Structural Change, **Economic Systems Research, Vol. 10, No. 1**, 63-78.

Wier, M. (1998) Sources of Changes in Emissions from Energy: A Structural Decomposition Analysis, **Economic Systems Research Vol. 10 No. 2,** 99-111.