1. **Introduction**

This part contains the step by step procedure adopted by us to calculate different dimensions of inter-sectoral carbon linkages of the total; inland; water and air transport sector of EU’s top seven emitters from 1995 to 2011. The hypothetical extraction method was adopted to measure the impact of inter-sectoral carbon linkages. Below we have mentioned step by step procedure including the partition of Leontief inverse matrix, partitioned Cella (1984) proposal and programs/software utilized and commands executed within those programs for inter-sectoral carbon linkages calculation. Presentation of these accounts will be helpful for possible future replication of results presented in our research.

|  |  |  |
| --- | --- | --- |
| Software | Version | Employment |
| MATLAB | R2016a | Major linkage calculations |
| Microsoft Excel | 2013 | Other calculations |

1. **Methodology:**
	1. *Partitioned Leontief inverse matrix and vector of the total output*

Miller & Lahr (2001) working on Cella (1984) proposal suggested the following partitioned structure for calculation of carbon linkages.

Partitioned technical coefficient matrix is presented as:

$$A=\left[\begin{matrix}A\_{c,c}&A\_{c,-c}\\A\_{-c,c}&A\_{-c,-c}\end{matrix}\right] (1)$$

Corresponding partitioned Leontief inverse matrix can be presented as:

$$\left(I-A\right)^{-1}=\left[\begin{matrix}R&RA\_{c,-c}L\_{-c,-c}\\L\_{-c,-c}A\_{-c,c}R&L\_{-c-,c}\left(I+A\_{-c,c}RA\_{c,-c}L\_{-c,-c}\right)\end{matrix}\right] (2)$$

Where $R=\left(I-A\_{c,c}-A\_{c,-c}L\_{-c,-c}A\_{-c,c}\right)$ and$ L\_{-c,-c}=\left(I-A\_{-c,-c}\right)^{-1}$. Corresponding total output in partitioned form can be presented as:

$$\left[\begin{matrix}X\_{c}\\X\_{-c}\end{matrix}\right]=\left[\begin{matrix}R&RA\_{c,-c}L\_{-c,-c}\\L\_{-c,-c}A\_{-c,c}R&L\_{-c-,c}\left(I+A\_{-c,c}RA\_{c,-c}L\_{-c,-c}\right)\end{matrix}\right]\left[\begin{matrix}Y\_{c}\\Y\_{-c}\end{matrix}\right] (3)$$

* 1. *Carbon linkages*

Impact of extraction of target block external carbon linkages in the partitioned form:

$$∆E=\left[\begin{matrix}e\_{c}&0\\0&e\_{-c}\end{matrix}\right]\left[\begin{matrix}R-a\_{c,c}&RA\_{c,-c}L\_{-c,-c}\\L\_{-c,-c}A\_{-c,c}R&L\_{-c,-c}A\_{-c,c}RA\_{c,-c}L\_{-c,-c}\end{matrix}\right]\left[\begin{matrix}Y\_{c}\\Y\_{-c}\end{matrix}\right] (4)$$

Where $∆E $represents the impact of extraction of a block’s intermediate imports and exports on total emissions, here$ a\_{c,c}=\left(I-A\_{c,c}\right)^{-1}$.

1. Calculations of carbon linkages under Modified hypothetical extraction method can be explained through following portioned matrices

Emissions from net backward linkage:

$$ENBL=\hat{u}e\_{-c}\left(L\_{-c,-c}A\_{-c,c}R\right)Y\_{c} (8)$$

Emissions from net forward linkage:

$$ENFL=\hat{u}e\_{c}\left(RA\_{c,-c}L\_{-c,-c}\right)Y\_{-c} (9)$$

Emissions from internal linkage:

$$EIL=\hat{u}e\_{c}\left(a\_{c,c}\right)Y\_{c} (10)$$

Emissions from mixed linkage:

$$EML=\hat{u}e\_{c}\left(R-a\_{c,c}\right)Y\_{c} (11)$$

Where$ \hat{u }$ represents an appropriate summation vector. ENBL, ENFL, EIL and ME represent emissions from net backward, net forward internal and mixed linkages. For further decomposition of ENFL and ENBL summation vector from equations 8 and 9 will be removed.

1. **Programming/ commands in MATLAB:**

Partitioned matrices will help us execute MATLAB commands/programming with comfort to calculate the desired results. It should be noted that there are several ways to design programs or run commands to obtain desired results we have tailored these as per our convenience. After basic calculations, extraction of technology matrix and importing/ inputting main values (see appendix) the following main steps were executed in MATLAB. In MATLAB program for ease of execution we have presented extracted block $c$ presenting total; inland; water and air transport as 1, and remaining blocks $-c $as 2.

At first step for simplicity, non-weighted linkages were estimated, i.e., without vector of final sectoral demand and emission intensity for that the following program/commands were executed in MATLAB[[1]](#footnote-1).

L22=(I-A22)^-1;

R=(1-A11-(A12\*L22\*A21))^-1;

a11=(1-A11)^-1;

MIX=R-a11;

FL=R\*A12\*L22;

BL=L22\*A21\*R;

Where MIX, FL, and BL denote mix linkage, forward linkage and backward linkage without final demand and environmental weights.

After these for the main values of net forward, net backward, mixed and internal emissions and further decomposition of emissions from net forward and backward linkages the following commands were executed. Where without summation values of ENFL and ENBL gives their decomposed emission values.

ENFL=e1\*FL\*Y2;

ENBL=e2\*BL\*Y1;

IE=e1\*a11\*Y1;

EML=e1\*MIX\*Y1;

Where ENFL, ENBL, IE, EML denote emissions from net forward, net backward, internal and emissions from mixed linkages. e1 & Y1 represent extracted blocks emission intensity & final demand. Whereas e2 (diagonalized) & Y2 represent respective intensities and final demand of remaining blocks.

**Appendix**

This appendix contains additional information about the programs/commands run in MATLAB to import data, and extraction of technology matrix. Which will make it much easier for the readers to replicate results produced in our research. Again there are many ways to import data into MATLAB in our case from .xlsx file. Here for illustration purposes, general file, sheet, and data range have been presented. For future replication, readers can change file/sheet names and data range according to their scenario, liking, and convenience.

Different heads of final demand including Household, Capital formation, Inventory change, government and exports were aggregated as Y in excel 2013. We ran the following programming to import sector wise data from our .xlsx file.

d1=xlsread('file.xlsx','sheet','range');

d2=xlsread('file.xlsx','sheet','range');

d3=xlsread('file.xlsx','sheet','range');

d4=xlsread('file.xlsx','sheet','range');

d5=xlsread('file.xlsx','sheet','range');

d6=xlsread('file.xlsx','sheet','range');

d7=xlsread('file.xlsx','sheet','range');

d8=xlsread('file.xlsx','sheet','range');

d9=xlsread('file.xlsx','sheet','range');

d10=xlsread('file.xlsx','sheet','range');

d11=xlsread('file.xlsx','sheet','range');

d12=xlsread('file.xlsx','sheet','range');

d13=xlsread('file.xlsx','sheet','range');

d14=xlsread('file.xlsx','sheet','range');

d15=xlsread('file.xlsx','sheet','range');

d16=xlsread('file.xlsx','sheet','range');

d17=xlsread('file.xlsx','sheet','range');

d18=xlsread('file.xlsx','sheet','range');

d19=xlsread('file.xlsx','sheet','range');

d20=xlsread('file.xlsx','sheet','range');

d21=xlsread('file.xlsx','sheet','range');

d22=xlsread('file.xlsx','sheet','range');

d23=xlsread('file.xlsx','sheet','range');

d24=xlsread('file.xlsx','sheet','range');

d25=xlsread('file.xlsx','sheet','range');

d26=xlsread('file.xlsx','sheet','range');

d27=xlsread('file.xlsx','sheet','range');

d28=xlsread('file.xlsx','sheet','range');

d29=xlsread('file.xlsx','sheet','range');

d30=xlsread('file.xlsx','sheet','range');

d31=xlsread('file.xlsx','sheet','range');

d32=xlsread('file.xlsx','sheet','range');

d33=xlsread('file.xlsx','sheet','range');

d34=xlsread('file.xlsx','sheet','range');

d35=xlsread('file.xlsx','sheet','range');

This would give us column vector wise intermediate data. Here file.xlsx= country wise input-output excel data files available from WIOD database. Sheet= year-wise IO tables sheets of respective countries within the file and range= scale (range) of industry-wise relevant columns of the intermediate matrix. d1 to d35 represent column vectors of intermediate sectoral demand. Afterward, the following command was executed to obtain the aggregated intermediate matrix. Of course, names/symbols assigned can be changed as per readers own case and convenience. To aggregate intermediate vectors of sectoral demand into matrix form the following command can be used:

IAD=[d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24 d25 d26 d27 d28 d29 d30 d31 d32 d33 d34 d35]

Where IAD represents the relevant intermediate matrix.

Next step is to import the vector of total output. For that, the following command was executed.

TO=xlsread('file.xlsx','sheet','range');

Where TO represents total output vector of respective economies from 1995 to 2011.

Now we are in a position to obtain the technology matrix of respective economies. For that we designed the following program.

ad1=IAD(:,1)/TO(1);

ad2=IAD(:,2)/TO(2);

ad3=IAD(:,3)/TO(3);

ad4=IAD(:,4)/TO(4);

ad5=IAD(:,5)/TO(5);

ad6=IAD(:,6)/TO(6);

ad7=IAD(:,7)/TO(7);

ad8=IAD(:,8)/TO(8);

ad9=IAD(:,9)/TO(9);

ad10=IAD(:,10)/TO(10);

ad11=IAD(:,11)/TO(11);

ad12=IAD(:,12)/TO(12);

ad13=IAD(:,13)/TO(13);

ad14=IAD(:,14)/TO(14);

ad15=IAD(:,15)/TO(15);

ad16=IAD(:,16)/TO(16);

ad17=IAD(:,17)/TO(17);

ad18=IAD(:,18)/TO(18);

ad19=IAD(:,19)/TO(19);

ad20=IAD(:,20)/TO(20);

ad21=IAD(:,21)/TO(21);

ad22=IAD(:,22)/TO(22);

ad23=IAD(:,23)/TO(23);

ad24=IAD(:,24)/TO(24);

ad25=IAD(:,25)/TO(25);

ad26=IAD(:,26)/TO(26);

ad27=IAD(:,27)/TO(27);

ad28=IAD(:,28)/TO(28);

ad29=IAD(:,29)/TO(29);

ad30=IAD(:,30)/TO(30);

ad31=IAD(:,31)/TO(31);

ad32=IAD(:,32)/TO(32);

ad33=IAD(:,33)/TO(33);

ad34=IAD(:,34)/TO(34);

ad35=IAD(:,35)/TO(35);

Where ad1 to ad35 represent block-wise technology column vectors of respective nations, the following command was executed to obtain the aggregated technology matrix.

AD=[ad1 ad2 ad3 ad4 ad5 ad6 ad7 ad8 ad9 ad10 ad11 ad12 ad13 ad14 ad15 ad16 ad17 ad18 ad19 ad20 ad21 ad22 ad23 ad24 ad25 ad26 ad27 ad28 ad29 ad30 ad31 ad32 ad33 ad34 ad35]

Where AD represents the technology matrix of the respective countries.

# **References**

Cella, G., 1984. The input-output measurement of interindustry linkages. *Oxford Bulletin of Economics and Statistics,* Volume 46, pp. 73-84.

Miller, R. E. & Lahr, M. L., 2001. A Taxonomy of Extractions. In: R. E. Miller & M. L. Lahr, eds. *Regional Science Perspectives in Economic Analysis : A Festschrift in Memory of Benjamin H. Stevens.* Amsterdam: Elsevier Science, pp. 407-441.

1. Below semi-colon was used to suppress the results from appearing on command window. [↑](#footnote-ref-1)