ONLINE APPENDIX

for

The CO_2 Content of Consumption Across U.S. Regions: A Multi-Regional Input-Output (MRIO) Approach

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A – DATA CONSTRUCTION

Computing the matrices presented in Section 2 requires the construction of the *A*, *Y* and *B* matrices and vectors. For the input-output matrices of U.S. sub-national regions, A^r, we rely on data compiled by the IMPLAN group[4]. IMPLAN constructs state-level input-output matrices from the national input-output table provided by the BEA as well as the National Income and Product Accounts (NIPA). Average (national) input coefficients are adjusted to match state-level output totals, which are themselves computed from both the BEA's output series and the U.S. Census Bureau's Annual Survey of Manufactures. The input-matrices for other countries are taken from the Global Trade Analysis Project GTAP version 7 (Narayanan and Walmsley, 2008) dataset as discussed in Caron and Rausch (2013).

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4 The IMPLAN dataset is compiled by the IMPLAN group LLC (www.implan.com). Comprehensive and detailed documentation of the IMPLAN dataset – including definitions of accounts and the various types of data sources used for the construction of the data – is available at http://implan.com/V4/index.php?option=com_multicategories&view=categories&cid=241:datainformation&Itemid=71.

The domestic final demand vectors for U.S. states are also taken from IMPLAN, which compiles them from Household Personal Consumption Expenditures (PCE) of the BEA's NIPA as well as the Consumer Expenditure Survey (CES). For energy goods (refined oil, coal, gas and electricity), we replace both the input requirement data in *A* and the final demand data in *D* with state-level data from the EIA's State Energy Data System (SEDS) dataset. This provides us with accurate final demand data for all energy goods, as well as aggregate energy input requirements for industry, agriculture and services at the state level.

MRIO analysis requires disaggregated estimates of input-output flows (A^{rs}) and demand flows (y^{sr}) on a bilateral basis. Such information is typically not available, as bilateral trade flows do not distinguish between intermediate or final consumption trade. Instead, we use a bilateral trade matrix by sector and share out input requirements and final demand according to the aggregate shares. That is, we assume that the share of final goods purchased from a particular region equals the share of imports from this region. For example, this means that although we know the amount of clothing exported from Texas to California, we do not how much of it is purchased as final goods to households. This value is thus assumed to correspond to the value of all imported clothing consumed by households in California multiplied by Texas' share of imports of clothing to California.

The same is done to infer the bilateral sourcing intermediate goods for each sector. The bilateral trade matrix, per sector, is built from four different sources. First, bilateral trade flows between U.S. states are taken, for the sectors for which the data is available (mostly in manufacturing and agricultural goods), from the Bureau of Transportation Statistics' Commodity Flow Survey (CFS). For services, bilateral trade flows are built to match state-level import and export totals (which are backed out using production and consumption data), with bilateral shares generated by a gravity model. Second, import and export totals for energy goods are taken from SEDS.

Bilateral U.S. state-to-country trade flows are based on the U.S. Census Bureau Foreign Trade Statistics State Data Series (US Census Bureau, 2010). Bilateral exports and imports are taken from, respectively, the Origin of Movement (OM) and State of Destination (SD) data series. The OM and SD data sets are available at the detailed 6-digit HS classification level, which permits aggregation to GTAP commodity categories. Finally, trade flows between countries outside of the U.S. are taken from GTAP.

There is considerable heterogeneity in the carbon content of electricity within the United States. Given the pooled nature of electricity production and transmission, one cannot assume that electricity produced in a given state is consumed in that state. Following the approach taken in Rausch *et al.* (2010, 2011), we consider the carbon intensity of electricity to be constant within electricity pools. Electricity is a homogeneous commodity within each of the six pools and non-traded across the pools. We define six regional electricity pools based on NERC regions and ISO's: Alaska, Western, ERCOT, Eastern, New England and New York. We broke NE and NY out of the Eastern Interconnect given the limited electricity trade flows between these two regions and the rest of the interconnect. **Table A3** displays the mapping between U.S. regions and electricity pools.[5]

Table A3. Geographic regions and electricity pools

Electricity Pool	Geographic Regions
West	California Mountain Pacific
East	Florida Mid-Atlantic Midwest North Central South Central Southeast
New England	New England
New York	New York
Texas	Texas

Table A4. Countries and international regions in the dataset, sorted by share of U.S. trade

	US Imports		**US Exports**		
	Trade Value *(bn$)*	**Embodied CO_2** *(Mt CO_2)*	**Trade Value** *(bn$)*	**Embodied CO_2** *(Mt CO_2)*	**Largest partner**
Canada	198.8	101.0	193.9	106.2	NEAS
Mexico	113.7	72.8	123.8	56.7	TX
China	48.7	24.7	141.6	245.7	CA
Japan	84.8	35.3	110.8	36.4	CA
Germany	62.2	30.1	73.0	25.1	NEAS
United Kingdom	57.7	24.8	56.7	19.4	NEAS
Korea	40.2	21.1	41.4	26.3	CA

5 We have also modeled interstate electricity trade through a bilateral trade matrix extracted from the National Renewable Laboratory's ReEDS model. The ReEDS model describes electricity flows between 136 Power Control Areas (PCAs) and represents existing transmission constraints. The carbon content of consumption is substantially the same whether we use our approach or ReEDS modeling.

	US Imports		US Exports		
	Trade Value *(bn$)*	Embodied CO_2 *(Mt CO_2)*	Trade Value *(bn$)*	Embodied CO_2 *(Mt CO_2)*	Largest partner
Rest of Western Asia	36.7	13.3	49.2	49.3	TX
France	33.5	16.0	30.3	9.4	NEAS
Taiwan	25.1	11.8	29.8	24.7	CA
Italy	21.5	10.3	28.0	12.5	NEAS
Belgium	19.0	13.4	16.4	8.0	NEAS
Malaysia	13.1	5.3	23.2	16.2	CA
Brazil	14.6	8.8	18.9	14.3	NEAS
Ireland	16.6	4.5	20.5	4.3	NEAS
Singapore	20.8	9.5	13.0	6.5	CA
Venezuela	5.2	2.8	19.5	20.2	TX
Switzerland	14.0	7.4	14.9	5.0	NEAS
Netherlands	18.7	10.1	11.5	7.5	NEAS
Caribbean	13.1	9.9	10.4	9.9	FL
Hong Kong	10.1	4.6	15.7	7.1	NEAS
Thailand	8.5	4.0	15.0	16.9	CA
Australia	18.9	9.2	9.4	7.6	NEAS
India	8.8	4.2	14.0	24.6	NEAS
Sweden	7.8	2.8	12.2	2.7	NEAS
Spain	10.6	5.8	8.5	4.4	NEAS
Russian Federation	7.8	3.2	9.6	30.8	NEAS
Nigeria	2.3	1.0	10.9	4.2	TX
Indonesia	5.3	2.4	9.4	11.3	SEAS
Turkey	5.1	4.1	5.1	4.9	NEAS
Austria	6.8	2.6	6.6	2.2	NEAS
Colombia	5.1	3.3	5.7	3.1	FL
Rest of Central America	4.8	4.5	4.5	1.8	SEAS
Denmark	4.9	2.5	6.4	2.0	NEAS
Norway	3.2	1.4	7.1	3.7	NEAS
Philippines	4.4	1.9	6.3	4.3	CA
South Africa	4.3	2.5	4.7	10.6	NEAS
Chile	4.1	2.7	4.2	3.1	NEAS
Rest of North Africa	2.6	1.2	5.5	5.6	TX
Vietnam	2.0	0.9	5.1	6.0	CA
Argentina	4.1	2.6	3.2	4.4	TX
Egypt	3.5	1.4	4.0	7.8	NEAS
Finland	2.9	1.5	3.6	2.5	NEAS
Peru	2.4	1.8	3.2	1.1	NEAS
Ecuador	1.9	1.4	3.5	1.1	CA
Pakistan	2.7	1.4	3.2	2.7	NEAS
Greece	4.1	2.7	1.9	1.0	NEAS
New Zealand	2.9	1.4	3.2	2.0	NEAS
Costa Rica	3.4	2.0	2.5	0.9	SEAS
Rest of South Central Africa	1.4	0.5	3.8	0.8	TX
Guatemala	2.8	2.5	1.6	0.7	TX
Rest of Central Africa	1.2	0.6	3.4	0.5	NEAS
Poland	3.2	1.4	2.4	2.7	NEAS
Hungary	3.0	1.1	2.3	1.1	NEAS
Portugal	1.6	0.7	2.4	1.2	NEAS
Rest of Western Africa	1.9	1.4	1.6	0.7	TX
Ukraine	1.6	0.8	2.0	5.4	NEAS

	US Imports		US Exports		
	Trade Value *(bn$)*	Embodied CO_2 *(Mt CO_2)*	Trade Value *(bn$)*	Embodied CO_2 *(Mt CO_2)*	Largest partner
Rest of East Asia	0.7	0.4	2.4	3.9	NEAS
Bangladesh	0.5	0.3	2.4	1.4	NEAS
Czech Republic	2.3	0.9	1.7	1.7	NEAS
Luxembourg	6.8	0.9	1.5	0.6	NEAS
Morocco	1.2	0.6	1.4	1.0	NEAS
Sri Lanka	0.4	0.2	1.7	1.2	NEAS
Cambodia	0.1	0.0	1.6	0.9	CA
Slovakia	0.6	0.3	1.3	0.9	CA
Croatia	0.7	0.4	1.1	0.7	NEAS
Romania	1.1	0.5	0.8	1.5	NEAS
Slovenia	0.7	0.5	0.8	0.4	NEAS
Rest of Eastern Africa	1.1	0.4	0.9	0.7	NEAS
Bulgaria	0.7	0.5	0.8	1.0	NEAS
Rest of Europe	1.0	0.6	0.6	0.9	NEAS
Rest of Oceania	0.8	0.4	0.8	0.8	CA
Nicaragua	0.5	0.3	0.8	0.4	SEAS
Rest of South African Customs Union	0.3	0.1	1.0	0.6	CA
Lithuania	0.6	0.3	0.7	0.7	NEAS
Kazakhstan	1.1	0.4	0.6	1.6	NEAS
Uruguay	0.5	0.3	0.6	0.3	NEAS
Malta	0.3	0.1	0.7	0.3	MOUN
Cyprus	0.4	0.2	0.6	0.3	NEAS
Tunisia	0.5	0.3	0.6	0.5	NEAS
Rest of Former Soviet Union	0.8	0.4	0.4	2.8	SEAS
Rest of EFTA	0.7	0.3	0.5	0.3	NEAS
Estonia	0.4	0.2	0.4	0.4	NEAS
Rest of South America	0.4	0.4	0.3	0.2	FL
Mauritius	0.2	0.1	0.5	0.3	NEAS
Belarus	0.3	0.1	0.5	1.4	NEAS
Rest of South Asia	0.4	0.2	0.4	0.3	NEAS
Rest of Southeast Asia	0.1	0.1	0.5	0.5	CA
Madagascar	0.1	0.0	0.5	0.2	NEAS
Iran	0.7	0.1	0.3	1.1	SEAS
Bolivia	0.3	0.2	0.3	0.4	FL
Panama	0.2	0.1	0.4	0.4	FL
Ethiopia	0.6	0.2	0.2	0.3	FL
Rest of North America	0.5	0.3	0.1	0.1	NEAS
Latvia	0.3	0.2	0.2	0.2	NEAS
Paraguay	0.6	0.2	0.1	0.1	FL
Azerbaijan	0.5	0.2	0.1	0.3	TX
Georgia	0.3	0.2	0.1	0.1	SEAS
Tanzania	0.3	0.1	0.2	0.2	NEAS
Uganda	0.1	0.1	0.2	0.1	NEAS
Senegal	0.2	0.2	0.1	0.1	NEAS
Botswana	0.1	0.0	0.2	0.2	NY
Albania	0.2	0.1	0.1	0.1	NEAS
Armenia	0.2	0.1	0.1	0.1	SEAS
Mozambique	0.2	0.1	0.1	0.1	NEAS
Zimbabwe	0.1	0.0	0.1	0.3	NEAS

	US Imports		US Exports		
	Trade Value *(bn$)*	**Embodied CO_2** *(Mt CO_2)*	**Trade Value** *(bn$)*	**Embodied CO_2** *(Mt CO_2)*	**Largest partner**
Malawi	0.1	0.0	0.1	0.1	SEAS
Rest of Eastern Europe	0.1	0.1	0.1	0.1	NEAS
Zambia	0.1	0.1	0.0	0.0	NEAS
Kyrgyzstan	0.1	0.0	0.0	0.1	NEAS
Laos	0.0	0.0	0.0	0.0	NEAS
Myanmar	0.1	0.0	0.0	0.1	NEAS

B – DECOMPOSING THE INDIRECT INTENSITY OF CONSUMPTION

Recall that we use region-specific estimates of the input-output matrices A^r and CO_2 intensity vectors F^r. To determine the sources of variability in indirect emissions, we re-compute consumption emissions under four different sets of assumptions (using average national values of A and F) and compare these results to our original MRIO calculations.

In particular, we aim to quantify the effect of these differences and make a direct comparison with the method used in Hassett *et al.* (2009) and Mathur and Morris (2012)—which we refer to as the HMM method in the main body of the text—we calculate CO_2 intensities while applying their simplifying assumptions to our data and regional aggregation We presents an algebraic description of each of the four sets of assumptions. In each case, we explain how E_C^r, the emissions embodied in consumption, is computed in each case.

US AVG – Average U.S. intensities

Here, we use average U.S. intensities for domestic production and imports in all regions. All cross-regional variation is explained by differences in consumption shares, as technological differences or differences in the within-sector composition of consumption are assumed away.

$$E_C^r = \acute{F}^{US-avg} \left(I - \acute{A}^{US-avg} \right)^{-1} \acute{C}^r$$

in which $\acute{F}^{US-avg}$ is the 1 by n vector of average U.S. CO_2 intensities of output, $\acute{A}^{US-avg}$ is the n by n average input-output matrix for the U.S. and $\acute{C}^r$ is redefined as the n by 1 vector of consumption in r (not bilateral): $\acute{C}^r = \sum_s y^{sr}$.

Theoretically, we would apply these assumptions only if our data were limited to average U.S. production intensity data (i.e. only a national I-O table), or if region-specific I-O tables were only available without an intra-national bilateral trade matrix (rendering us unable to compute region-specific indirect embodied emissions).

US AVG INDIRECT (HMM) - U.S. average indirect intensities

As in Hassett *et al.* (2009) and Mathur and Morris (2012), we assume U.S. average CO_2 intensities for non-energy goods, but use region-specific values for direct emissions (including electricity).

$$E_C^r = \acute{F}^{US} \left(I - \acute{A}^{US} \right)^{-1} \acute{C}^r_{non-ele} + f^r_{ele} c^r_{ele}$$

where f^r_{ele} is the average CO_2 coefficient of output for all states within region r's electricity pool.

Theoretically, we would apply these assumptions if, in addition to the U.S. AVG data, we knew cross-regional differences in the emissions intensity of fossil fuels and electricity only.

US AVG INDIRECT+INT IMP – Using data on the intensity of international imports.

Domestic emissions are computed as above, but we use observed average U.S. emission intensities for international imports.

$$E_C^r = \acute{F}^{US-avg,W} \left(I - \acute{A}^{US-avg,W} \right)^{-1} C^{r\,\prime}_{w\,non-ele} + f^r_{ele} c^r_{ele}$$

where $\acute{F}^{US-avg,W} = \left[\acute{F}^{US} f^1 \ldots f^r \quad US \right]$ is the a vector of size 1 by (number of international regions +1) and

$$\acute{A}^{US-avg,W} = \begin{bmatrix} \acute{A}^{US} & A^{US,R} \\ A^{R,US} & A^{RR} \end{bmatrix}$$

is the input-output matrix that would result if the U.S. was treated as a single unit. Finally, $\acute{C}_{w}^{r}$ would be an *nR* by 1 vector of *r*'s consumption, where bilateral shares would simply correspond to U.S. average bilateral shares $_{US}^{s}$:

$$\acute{C}_{w}^{r}=\begin{bmatrix} {}_{US}^{1}\acute{C}^{r} \\ {}_{US}^{s}\acute{C}^{r} \end{bmatrix}$$

Theoretically, we would apply these assumptions if, in addition to the U.S. AVG INDIRECT data, we had bilateral international trade data linked to foreign production intensity data, but without the exact sourcing of imports by sub-national region.

AVG INT IMP – Using U.S. average intensities for international imports.

This set of assumptions uses the intra-national bilateral trade data to compute indirect intensities of all goods, accounting for differences in domestic sourcing, but uses U.S. average intensities for international imports

$$E_{C}^{r}=\acute{F}^{w-avg}\left(I-\acute{A}^{w-avg}\right)^{-1}C_{w-avg}^{r\,\prime}$$

where $\acute{F}^{w-avg}=\left[f^{state\,1}f^{state\,2}\ldots f^{stateS}\,\acute{F}^{US}\right]$ is a vector of size 1 by (number of U.S. regions +1) where international production is assumed to have the average U.S. production intensity.

$$\acute{A}^{w-avg}=\begin{bmatrix} A^{s1s1} & A^{s1,US} \\ A^{US,s1} & \acute{A}^{US} \end{bmatrix}$$

is the input-output matrix that we obtain if the foreign imports where aggregated to a single unit and assumed to follow U.S. intensities. Finally, $\acute{C}^{r}_{w-avg}$ would be a (number of U.S. regions regions +1) by 1 vector of *r*'s consumption, where all internationally sourced consumption is aggregated to into one element.

Theoretically, we would apply these assumptions if we had all the data necessary for MRIO analysis within the US, but without international import data.

In all cases, the direct emissions from household fossil fuel use will be identical.

Decomposition results

Table A5 displays, for all regions, the CO_2 intensity of consumption for each of the above groups compared to the full MRIO estimates. The left side of the table shows the total values encompassing both direct and indirect consumption of CO_2. The right side shows values for the indirect intensity only—this is where we expect differences across assumptions to be larger. The last five rows of Table A5 describe the distribution of intensities under each set of assumptions.

Table A5. CO_2 intensity of consumption results: comparing MRIO results to assumption sets.

	MRIO	**US AVG**	**US AVG INDIR. (HMM)**	**US AVG INDIR. +INT IMP**	**AVG INT IMP**	**MRIO**	**US AVG**	**US AVG INDIR. (HMM)**	**US AVG INDIR. +INT IMP**	**AVG INT IMP**
Data Sources										
Non-Elec. Production	RSV	AVG	AVG	AVG	RSV	RSV	AVG	AVG	AVG	RSV
Elec. Production	RSV	AVG	RSV	RSV	RSV	RSV	AVG	RSV	RSV	RSV
International Imports	RSV	AVG	AVG	RSV	AVG	RSV	AVG	AVG	RSV	AVG
Region	*CO_2 Intensity—Total (kg/$)*					*CO_2 Intensity—Indirect Only (kg/$)*				
New England	0.350	0.444	0.410	0.444	0.317	0.182	0.243	0.243	0.277	0.149
New York	0.317	0.415	0.361	0.395	0.270	0.197	0.241	0.241	0.275	0.149
Mid-Atlantic	0.463	0.446	0.461	0.493	0.442	0.246	0.244	0.244	0.276	0.224
Southeast	0.569	0.507	0.531	0.564	0.565	0.285	0.247	0.247	0.280	0.281
Florida	0.581	0.495	0.528	0.561	0.537	0.294	0.241	0.241	0.274	0.250
Midwest	0.515	0.470	0.485	0.516	0.495	0.279	0.249	0.249	0.281	0.258
North Central	0.576	0.490	0.506	0.543	0.559	0.317	0.247	0.247	0.284	0.3003
South Central	0.661	0.507	0.532	0.565	0.736	0.380	0.251	0.251	0.284	0.454
Texas	0.562	0.503	0.479	0.512	0.563	0.328	0.244	0.244	0.277	0.328
Mountain	0.477	0.477	0.459	0.494	0.439	0.267	0.248	0.248	0.283	0.228
Pacific	0.441	0.447	0.428	0.459	0.389	0.257	0.244	0.244	0.276	0.205
California	0.356	0.399	0.388	0.413	0.333	0.213	0.245	0.245	0.269	0.189
Mean	0.484	0.464	0.464	0.496	0.464	0.265	0.245	0.245	0.278	0.245
Standard Dev.	0.098	0.038	0.055	0.057	0.113	0.048	0.003	0.003	0.005	0.066
Var. Coeff.	0.202	0.082	0.119	0.115	0.244	0.182	0.011	0.011	0.017	0.270
Minimum	0.317	0.399	0.361	0.395	0.270	0.182	0.241	0.241	0.269	0.149
Maximum	0.661	0.507	0.532	0.565	0.270	0.380	0.251	0.251	0.284	0.455

Data sources are RSV (Region-Specific Values) and AVG (Average U.S. values). CO_2 intensity measured in kg/$ of consumption. Note that for Indirect Only results, U.S. AVG and U.S. AVG INDIR. generate the same values.

As seen in the last five rows, the restrictive assumptions of **US AVG** lead to intensity values that are, on average, lower than MRIO results (average of 0.46 instead of 0.48 kg/$). This difference indicates that internationally imported goods are more CO_2 intensive than domestic goods on average—and, more importantly, that they also have dramatically lower variance. The coefficient of variation (standard deviation standardized by the mean) of indirect emissions in this case is only 0.01 – much less than the 0.18 found using MRIO.

These numbers indicate that variations in consumption patterns explain only a small part of the regional disparities in the average CO_2 content of consumption, most of which is explained by differences in technology and production intensities. Under the **US AVG INDIRECT (HMM)** assumptions, the coefficient of variation increases slightly, from 0.08 kg/$ to 0.12 kg/$, but nonetheless it remains much lower than under MRIO. Under **US AVG INDIRECT+INT IMP**, we identify the importance of accounting for the CO_2 intensity of international imports: these assumptions increase the mean intensity of US consumption, as goods imported from foreign sources have higher intensities on average, but they do not affect variability across regions. Finally, **AVG INT IMP** shows the importance of accounting for international trade flows. These values closely resemble MRIO results, although the mean is lower.

From a practical standpoint, the most important aspect to consider when comparing methodologies might be the precision of estimates for particular regions that policy makers may care about. To investigate this, we also express differences in methodologies by computing the difference in carbon estimates relative to MRIO estimates. These differences are measured as 100 × (counterfactual estimate / MRIO estimate -1). **Table A6** summarizes the median and maximum differences found under each set of assumptions. The maximum is computed both across the 12 aggregated regions (remaining comparable with Hassett *et al.* (2009) and Mathur and Morris (2012) who work at a similar level of aggregation), and across all 50 states.

Table A6. Median and maximum differences in CO_2 intensity of consumption across assumptions (in %).

	Total			**Indirect only**		
	Media	*Max*	*Max*	*Media*	*Max*	*Max*
US AVG	11.47	31.06	53.84	16.69	34.01	69.45
HMM - US AVG	9.14	19.55	51.43	16.69	34.01	69.45
US AVG INDIRECT+INT	6.08	27.02	47.05	11.25	51.84	63.53
AVG INT IMP	5.98	12.24	24.39	10.95	19.70	32.93

C – TRADE FLOWS

Table A7. CO_2 embodied in bilateral trade flows, including with trade with the largest international trading partners (Mt CO_2)

		DESTINATION																										
		Domestic												International														
		GNEN	NY	MATL	SEAS	FL	SMWE	NNCE	NSCE	TX	NMOU	PACI	CA	CHN	JPN	KOR	TWN	IND	CAN	MEX	VEN	FRA	DEU	ITA	GBR	RUS	XWS	Other	Export total
ORIGIN Domestic	NEN		5	3	2	1	3	1	1	1	1	0	1	1	1	1	0	0	3	0	0	1	2	0	1	0	0	4	58
	NY	4		7	4	2	5	1	1	2	1	0	1	1	1	0	0	0	3	1	0	1	1	0	1	0	1	5	43
	MATL	6	18		15	5	20	4	2	4	3	1	4	2	4	2	1	0	9	3	0	2	4	1	4	0	2	16	196
	SEAS	5	8	19		28	32	10	12	13	7	3	11	4	6	2	1	0	15	7	0	2	6	2	4	1	2	24	298
	FL	2	2	3	15		5	1	2	3	2	2	2	1	1	1	0	0	1	1	0	1	1	0	1	0	1	8	58
	MWE	8	13	34	30	8		34	8	11	9	6	14	3	6	2	1	1	36	8	0	4	6	2	5	1	2	22	383
	NCE	2	3	5	9	4	36		8	9	9	3	10	2	3	2	1	0	10	4	0	1	3	1	2	0	1	11	196
	SCEN	2	3	4	17	6	10	10		23	6	2	9	2	3	2	1	1	5	3	0	1	2	1	1	0	1	14	139
	TX	4	5	6	16	8	13	11	22		14	3	11	6	6	6	4	1	14	35	1	3	5	2	4	1	4	40	243
	MOU	3	3	4	5	2	11	8	4	15		5	77	2	2	1	1	0	4	3	0	1	2	1	2	0	1	11	195
	PACI	2	1	2	2	1	4	3	1	2	4		18	1	3	1	1	0	4	1	0	1	1	0	1	0	1	7	73
	CA	5	3	4	6	3	9	5	3	9	13	6		3	6	3	2	0	6	5	0	2	3	1	3	0	1	15	119
International	CHN	8	14	26	36	8	35	12	4	22	6	9	66																
	JPN	1	2	4	5	1	6	1	0	2	1	2	13																
	KOR	1	1	2	4	0	5	1	0	3	1	1	8																
	TWN	1	2	2	3	1	3	2	0	2	1	1	7																
	IND	1	6	4	3	1	3	1	1	3	0	0	3																
	CAN	10	10	11	10	2	33	8	2	4	4	5	8																
	MEX	2	3	3	5	2	9	1	3	17	2	1	8																
	VEN	0	0	4	1	2	1	0	4	7	0	0	0																
	FRA	1	1	2	2	0	1	0	0	1	0	0	1																
	DEU	2	1	6	5	1	4	1	1	1	1	0	2																
	ITA	1	2	2	2	1	2	0	0	1	0	0	1																
	GBR	1	1	4	4	1	2	1	1	2	1	0	2																
	RUS	1	2	9	2	1	5	1	3	3	0	1	2																
	XWS	1	6	9	3	1	3	1	6	10	1	1	7																
	Other	14	22	43	36	13	25	7	9	24	8	6	35																
	Import total	**113**	**139**	**284**	**314**	**104**	**395**	**183**	**107**	**194**	**122**	**81**	**325**																

Note: This table shows emissions embodied in bilateral trade flows (from row to column) in Mt CO_2. As an example, there are 8 million tons of emissions occurring in China associated with traded goods flowing from China to New England.

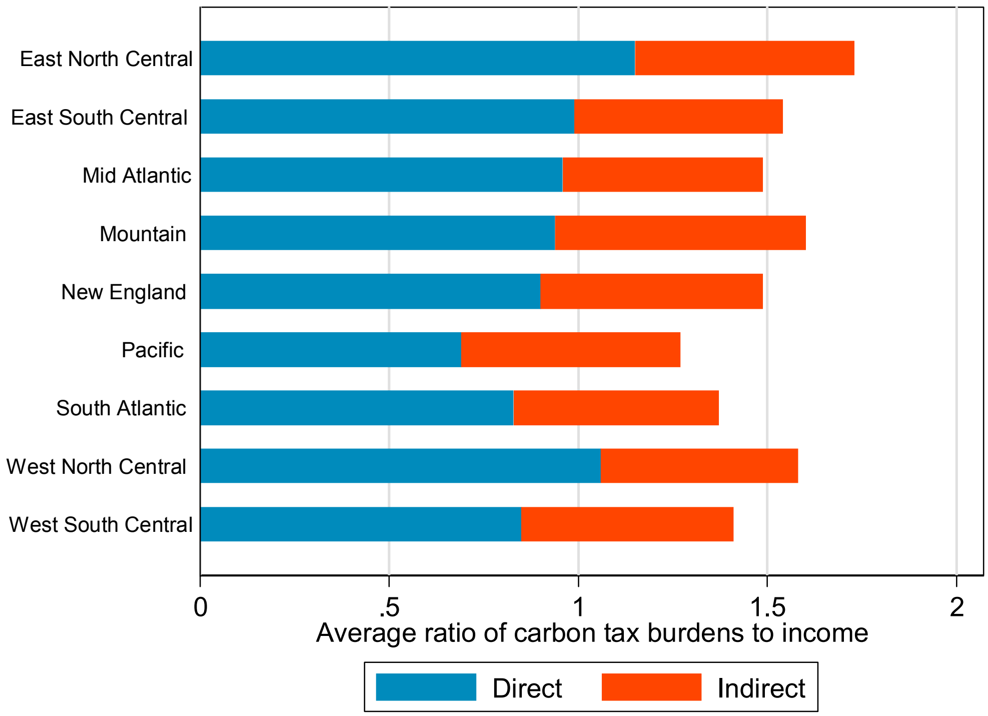

Figure A2. Regional distribution of carbon tax burden. (Source: Mathur and Morris (2012), Table 7)

D – MRIO ILLUSTRATED WITH FLOW CHARTS

The following flow charts are meant to illustrate the various ways of accounting for flows of CO_2 emissions, represented here as arrows. In each chart, full squares represent the CO_2 emitted at each point on the production to consumption chain. Striped squares represent embodied emissions. White squares mean that a particular flow is not taken into account. The left hand side represents a generic region in the model, and the right-hand side represents an aggregation of its trading partners (any or all other regions). The arrows illustrate the flow of CO_2, with color designating the type of flow.

Figure A3 illustrates all regional flows included in the emissions accounting exercise underlying Figure 3. Regional production emissions correspond to all full squares: the carbon emitted in the region. Consumption-based emissions are the sum of all flows flowing into the consumption block, whether it was emitted in intermediate or final good production, within or out of the region. **Figure A4** illustrates the computation of the CO_2 intensity of consumption displayed in Figure B1, and distinguishes between direct fossil fuel, direct electricity and indirect emissions.

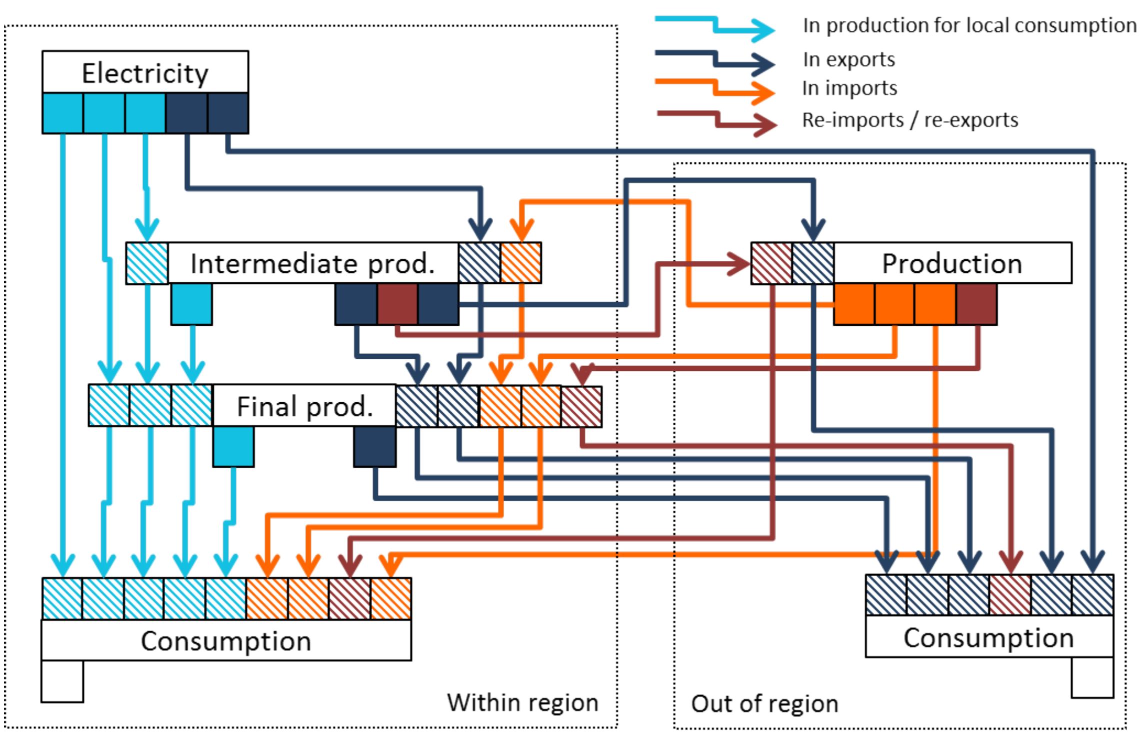

Figure A3. Flow chart describing CO_2 accounting of production, consumption and re-exports.

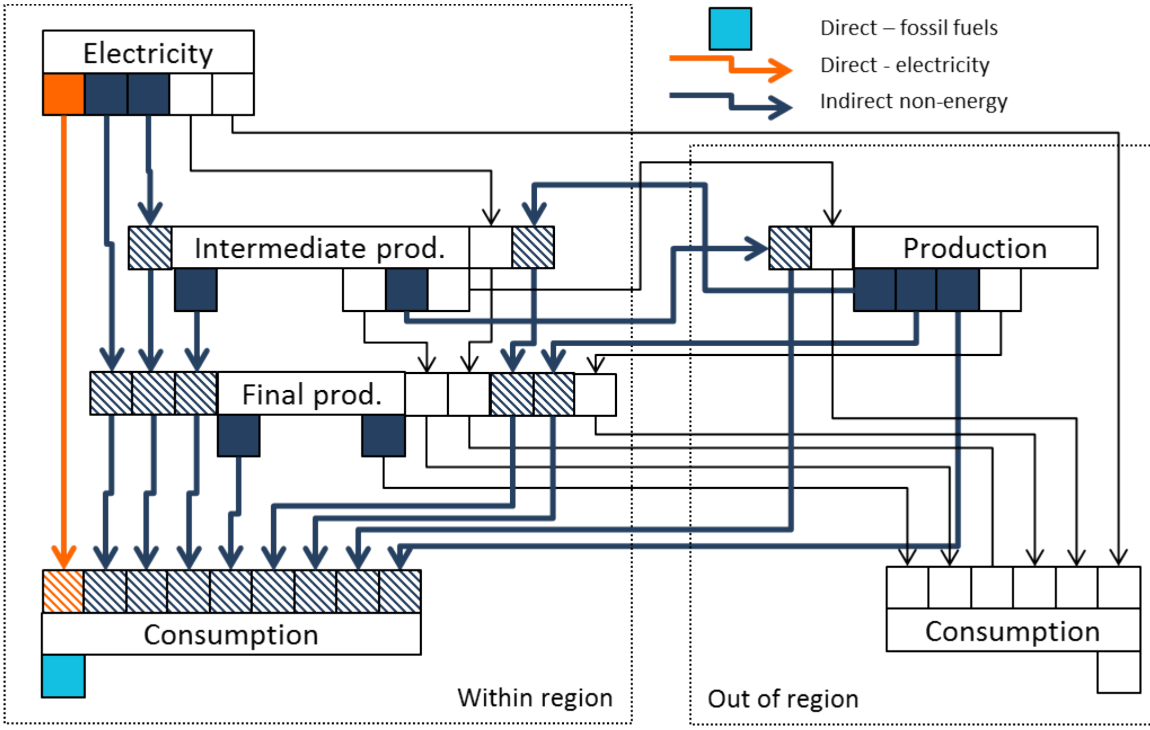

Figure A4. Flow chart describing the computation of the CO_2 content of consumption.