

The Sustainability Practitioner's Guide to Multi-Regional Input-Output Analysis

Edited by
JOY MURRAY AND MANFRED LENZEN



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**THE SUSTAINABILITY PRACTITIONER'S
GUIDE TO MULTI-REGIONAL INPUT-
OUTPUT ANALYSIS**

JOY MURRAY, EDITOR
MANFRED LENZEN, EDITOR



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Chapter 16: Accounting for Environmental Responsibility: A Case of Asian Countries Using the Asian International Input-Output Model

Xin Zhou and Alexandra Marques

Introduction

The main driver for climate change is the accumulation of greenhouse gases (GHG) in the atmosphere, which results from anthropogenic activities, namely the burning of fossil fuels and land use changes. The climate system is a common resource; its protection requires joint efforts and global collaboration. As the first milestone in tackling climate change, the Kyoto Protocol committed 37 industrialized countries and the European Union to collectively reduce their GHG emissions by an average of 5% against 1990 levels.

Due to the ‘common but differentiated responsibilities’, developing countries did not commit themselves to any quantified mitigation. Though they account for less than one quarter of historical emissions, over three quarters of future emissions growth will likely come from today’s developing countries because of their rapid population and GDP growth. Therefore all emitting nations should take some responsibility.

In order to determine the emissions each country is responsible for and to monitor the progress towards established targets, Kyoto requires that countries report, through national GHG inventories, "emissions and removals taking place within national (including administered) territories and offshore areas over which

the country has jurisdiction"¹. Through these national GHG inventories only direct emissions are accounted for, international transportation and indirect effects associated with international trade are excluded. This is the *producer responsibility principle*.

There are both pros and cons for the producer responsibility principle. On the one hand, producer responsibility is underpinned by the polluter-pays-principle, which has been endorsed by the OECD countries since mid-1970s. In practice, direct emissions are easier to estimate, monitor and report. Also accounting for emissions within the boundary of national jurisdiction respects the sovereignty of states.

On the other hand, the shortcomings of this approach are numerous and their consequences are important. The producer responsibility principle makes impossible the allocation of international transportation or other indirect effects, allows for carbon leakage phenomena through international trade and creates issues of fairness and competitiveness difficult to overcome^{2,3}. Kyoto places all responsibility on producers. A country whose economy is mainly supported by exports will have, comparatively, more direct emissions than a non-exporting country. This framework is unlikely to be accepted by rapidly developing countries, like China or India, whose economies are highly dependent on exports and have the highest CO₂ emissions growth rates⁴.

To address these shortcomings, it is necessary to incorporate international trade and consider other responsibility principles in assessing national inventories. 'Embodied emissions' is such an indicator which tries to address consumer responsibility by assessing the emissions generated from all upstream stages, no matter from where, in the supply chain. In contrast to the producer responsibility principle, the *consumer responsibility principle* requires consumers to be responsible for all upstream emissions embodied in their consumption.

As a counterpart to the upstream responsibility in a supply chain, the downstream responsibility in a sales chain requires suppliers be responsible for the emissions generated from all downstream stages. Because of their supply, the downstream producers are enabled directly or indirectly to produce and hence to emit. The suppliers benefit from the emissions by obtaining income and therefore should assume the responsibility. 'Enabled emissions' is used as an indicator to assess such *downstream responsibility* or *income responsibility principle* (see Marques *et al.*, 2012 in Further readings).

¹ UNFCCC (1998). *Kyoto Protocol to the United Nations Framework Convention on Climate Change*. Technical Report. Bonn: United Nations Framework Convention on Climate Change (UNFCCC).

² Peters, G., & Hertwich, E. (2008). CO₂ embodied in international trade with implications for global climate policy. *Environmental Science and Technology* 42, 1401-1407.

³ Whalley, J., & Walsh, S. (2009). Bringing the Copenhagen global climate change negotiations to conclusion. *CESifo Economic Studies* 55, 255-285.

⁴ Raupach, M.R., Marland, G., Ciais, P., Quéré, C.L., Canadell, J.G., Klepper G., & Field, C.B. (2007). *Global and regional drivers of accelerating CO₂ emissions*. Proceedings of the National Academy of Sciences, 485, 10288-10293.

Input-output analysis can be used to allocate upstream emissions or downstream emissions systematically while avoiding the double-counting problem. In doing so, ultimate upstream responsibilities are allocated to the consumers of the final products (such as households) by using the Leontief inverse and ultimate downstream responsibilities are allocated to the providers of primary factors (such as workers, investors, land owners, etc.) by using the Ghosh inverse.

By either of the approaches, however, the nature of each agent in the production chain being both a supplier and a customer at the same time cannot be captured, leaving the fairness issue unsolved. New metrics, which aim to recognise shared producer and consumer responsibility (Gallego and Lenzen, 2005; Lenzen *et al.*, 2007) or shared upstream and downstream responsibility (Rodrigues and Domingos, 2008), are therefore introduced.

In this chapter we illustrate an application of the Asian International Input-Output Model (AIO) in assigning environmental responsibility across countries and compare national inventories based on producer responsibility, consumer responsibility, income responsibility and shared environmental responsibility.

Asian International Input-Output Model

AIO was constructed by the Institute of Developing Economies, Japan External Trade Organisation (IDE-JETRO)⁵. IDE developed the first AIO for 1985 and updated it every five years until the year 2000. The AIO 2000 is compiled for 7 sectors, 24 sectors and 76 sectors based on different sectoral aggregation schemes. In our calculations we apply the 24-sector version of the AIO 2000. As introduced in Chapter 4, AIO 2000 is a Chenery-Moses type of multiregional model established based on national IO tables of ten economies including Indonesia, Malaysia, the Philippines, Singapore, Thailand, Mainland China, Taiwan, the Republic of Korea, Japan and the USA.

The simplified framework of the AIO 2000 is shown in Figure 1. Matrix AX represents interregional and inter-industrial transactions of intermediate goods. Matrix F represents final demand in ten economies that are supplied by themselves. E represents exports from ten economies to Hong Kong, EU and the rest of the world (ROW), respectively. Hong Kong and EU are treated separated from the rest of the world to recognize them as important trading partners of the ten economies. X represents total outputs by row or total inputs by column of ten regions. AX , F , E and X are expressed in producer prices. International transportation costs for trade among ten economies are presented as BA for intermediate goods and BF for final goods. Imports from Hong Kong, EU and ROW to ten economies are represented as import matrix IA for intermediate goods and IF for final goods in CIF (cost, insurance and freight) prices. DA and DF represent duties and taxes for all interregional trade and imports from Hong Kong, EU and ROW. V is value added, further disaggregated into wages and

⁵ IDE-JETRO (2006). Asian International Input-Output Table 2000, Vol. 1, Explanatory Notes. Chiba: Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO).

salary, operating surplus, depreciation of fixed capital and indirect taxes less subsidies.

Figure 1: Simplified framework of AIO 2000.

	Intermediate demand in ten economies	Final demand in ten economies	Export to Hong Kong, EU and ROW	Total outputs
Supply from ten economies	AX	F	E	X
Freight & insurance	BA	BF		
Imports from HK, EU and ROW	IA	IF		
Duties & taxes	DA	DF		
Value added	V			
Total inputs	X			

Source: IDE-JETRO (2006)

Reading by row, total outputs are distributed to satisfy intermediate demand, final demand and exports. By column, total inputs include purchases of intermediate goods and imports for production, payment for international transportation and tariff and payment for primary factors, such as labor, capital and governmental taxes, etc.

Accounting for National Emissions Based on Different Responsibility Indicators

We use an example of automobiles manufactured in Japan (see Box 1) to illustrate the ways of accounting for national emissions based on different responsibility indicators.

Box 1 Manufacture of automobiles

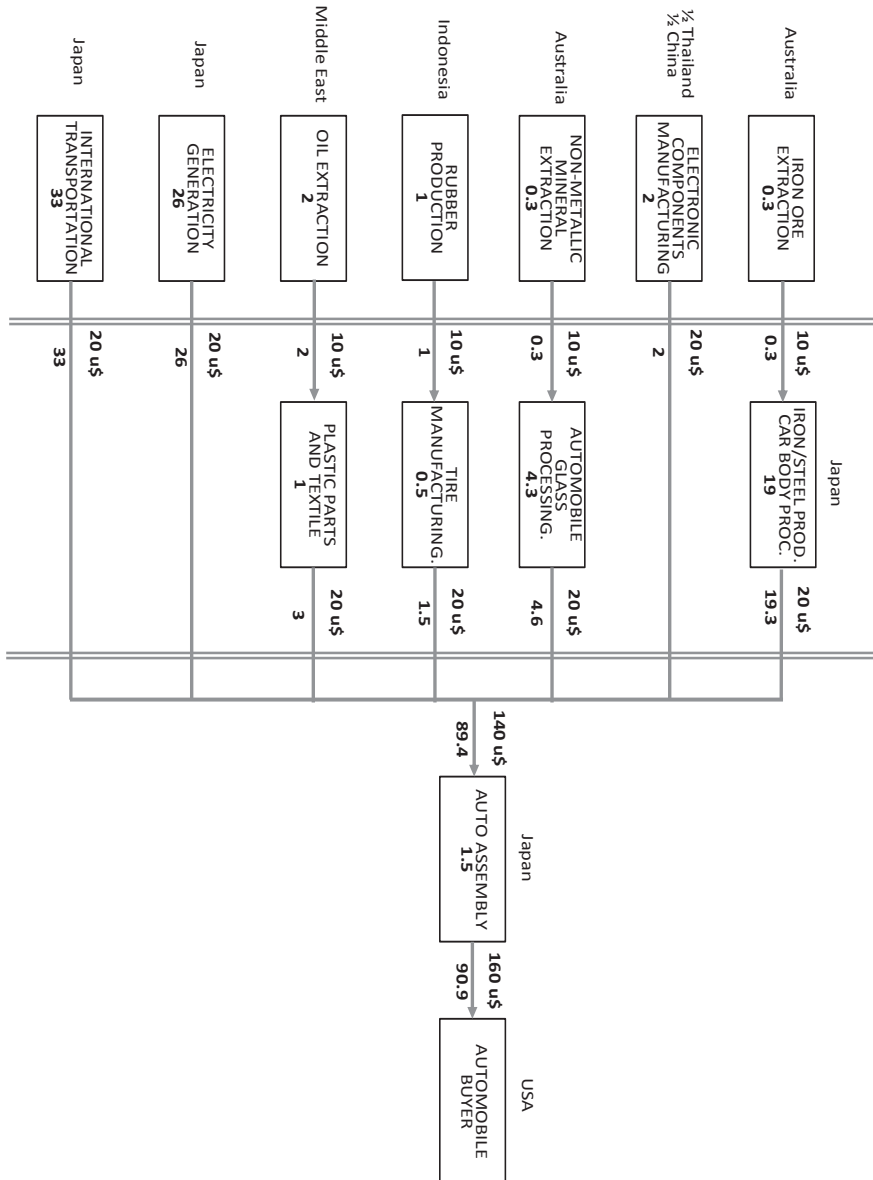
Automobile manufacture in Japan is completed through international purchase of minerals, components and parts that are produced in different countries around the world. Iron ore is imported from Australia for the production of iron and steel that is used for the car body. Electronic components are produced either domestically or imported from Thailand and China. Non-metallic ores are imported from Australia or Vietnam to produce automobile glass. Rubber is imported from South-East Asian countries for the production of tires. Plastic parts and textiles for doors, seat covers and car interior, etc. are manufactured by petrochemical industries which import naphtha and oil from Middle East countries. All the components and parts are then sent to the automobile assembly industry to produce a finished car for sale.

Emissions from different stages of production

Emissions data and source countries shown below are used only for illustrative purpose and do not represent the real situation.

Stages/actors	Direct emissions	Source countries
Iron ore extraction	0.3 unit	Australia
Iron/steel and car body processing	19 units	Japan
Electronic components manufacturing	2 units	Thailand (1/2) and China (1/2)
Non-metallic mineral extraction	0.3 unit	Australia
Automobile glass processing	4.3 unit	Japan
Rubber production	1 unit	Indonesia
Tire manufacturing	0.5 unit	Japan
Oil extraction	2 units	Middle East Countries
Plastic parts and textile manufacture	1 unit	Japan
Electricity generation	26 units	Japan
International transportation	33 units	Japan
Automobile assembly	1.5 units	Japan
Total	90.9 units	

Figure 2: The upstream carbon responsibility, passed on from upstream suppliers to the final consumer through a simplified supply chain of automobile production (u\$ = dollar units).



By producer responsibility indicator, the source country is responsible for the corresponding direct emissions. Therefore for one automobile manufactured in Japan, Japan is responsible for $19+4.3+0.5+1+26+33+1.5=85.3$ units of emissions; Australia is responsible for $0.3+0.3=0.6$ unit; Thailand and China are responsible for 1 unit, respectively; Indonesia is responsible for 1 unit, and Middle East countries are responsible for 2 units of emissions.

By consumer responsibility indicator, the person who bought the car, i.e. the final consumer, is responsible for all the emissions generated from upstream productions, i.e. 90.9 units. If the person resides in the USA, then the USA, and none of the emissions source countries, is responsible for the emissions. The concept of consumer responsibility within this example is schematized in Fig.2.

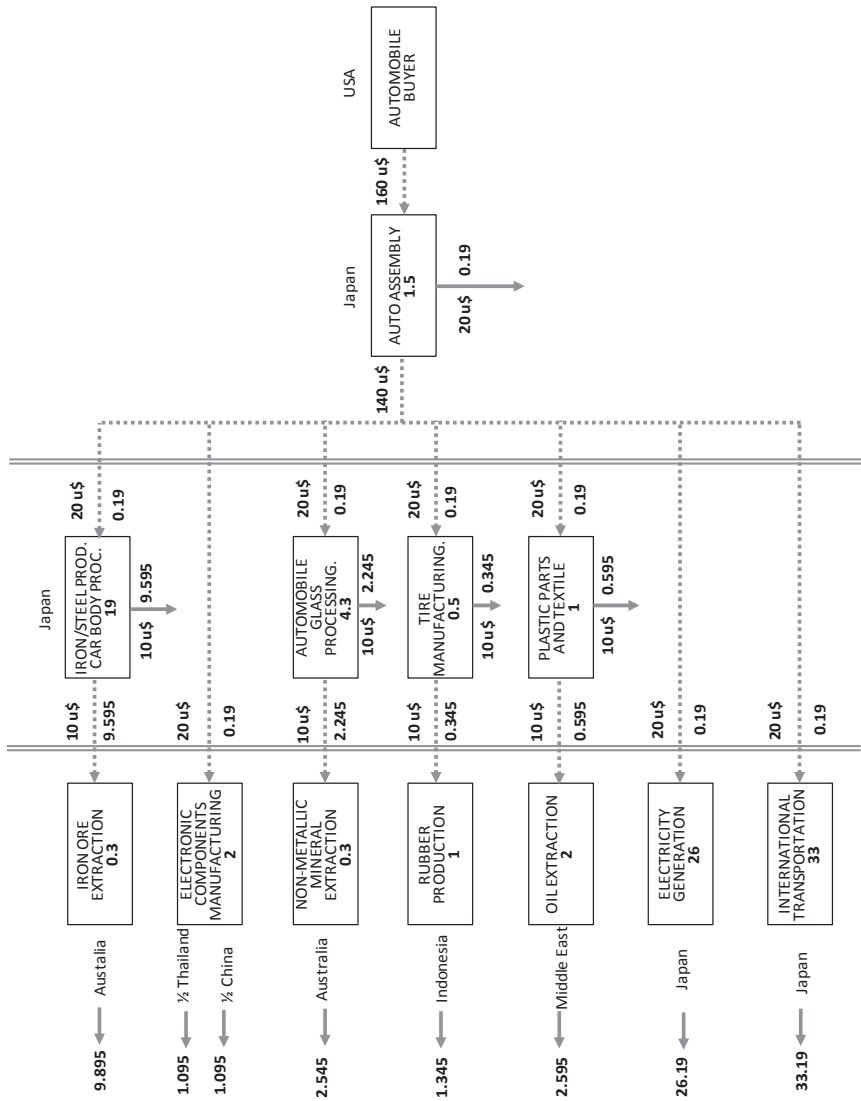
Under the income responsibility principle, the providers of primary factors who enable emissions downstream assume the responsibility. Each sector employs primary factors that receive a certain amount of income and therefore the providers of the primary factors hold part of income responsibility. Figure 3 presents the downstream carbon responsibility that flows from the final consumer to the providers of primary factors of production. Under this approach, each sector in the supply chain will share its direct and downstream emissions with its suppliers (both direct and indirect) based on their income. We also assume that the providers of primary factors reside in the same country as the industry that they provide for.

For the example in Box 1, the emissions generated by the auto assembly manufacturer (1.5 units) are allocated among the providers of primary factors both for the industry itself and for seven upstream intermediate suppliers (the iron and steel production and car body processing, electronic components manufacturing, and automobile glass processing, etc.). Since in this case the providers of primary factors for the auto assembly received 20 u\$ and the auto assembly paid each of the seven upstream suppliers the same 20 u\$, the income responsibility of the primary factors of the auto assembly productions is 1.5 units shared equally between the seven upstream suppliers and the auto assembly industry itself: $1.5/8 = 0.19$ units of emissions. It is the same amount of emissions that the auto-assembly passes to each of its direct upstream suppliers. These upstream suppliers will then transfer their income responsibility (direct emissions plus the emissions they enabled in the auto assembly) to the providers of primary factors for the industry itself and for other upstream suppliers.

Following this rationale, we see that the providers of primary factors of the iron ore extraction sector enabled the emissions of 9.895 units (i.e. $9.595+0.3$) and the providers of the primary factors of the non-metallic extraction sector 2.545 units. Thus, in this automobile production chain, Australia enabled the emissions of 12.44 units, in order to receive 20 u\$ of economic benefit. Electronic components manufacturers' primary factor providers enabled the emissions of 2.19 units, of which 1.095 units were enabled by Thailand and 1.095 units enabled by China; each receiving an economic benefit of 10 u\$. The providers of primary factors of the rubber production sector in Indonesia enabled the generation of 1.345 units of emissions and the providers of the primary factors of the oil extraction sector in the Middle East enabled 2.595 units of emissions. In this supply chain, Japan is the country whose providers of primary factors enabled the most emissions, and the country that received the most economic benefit as well. The income responsibility of Japan is the sum of the emissions enabled by the providers of the primary factors for electricity generation, international transportation, iron and steel production and car body processing, automobile car glass processing, tire manufacturing, plastic parts and textile manufacturing and the automobile assembly sectors. This corresponds to

$33.19+26.19+0.595+0.345+2.245 +9.595+0.19=72.35$ units of emissions and an economic benefit of 100 u\$. The USA, where the consumer resides, is not responsible for any emissions.

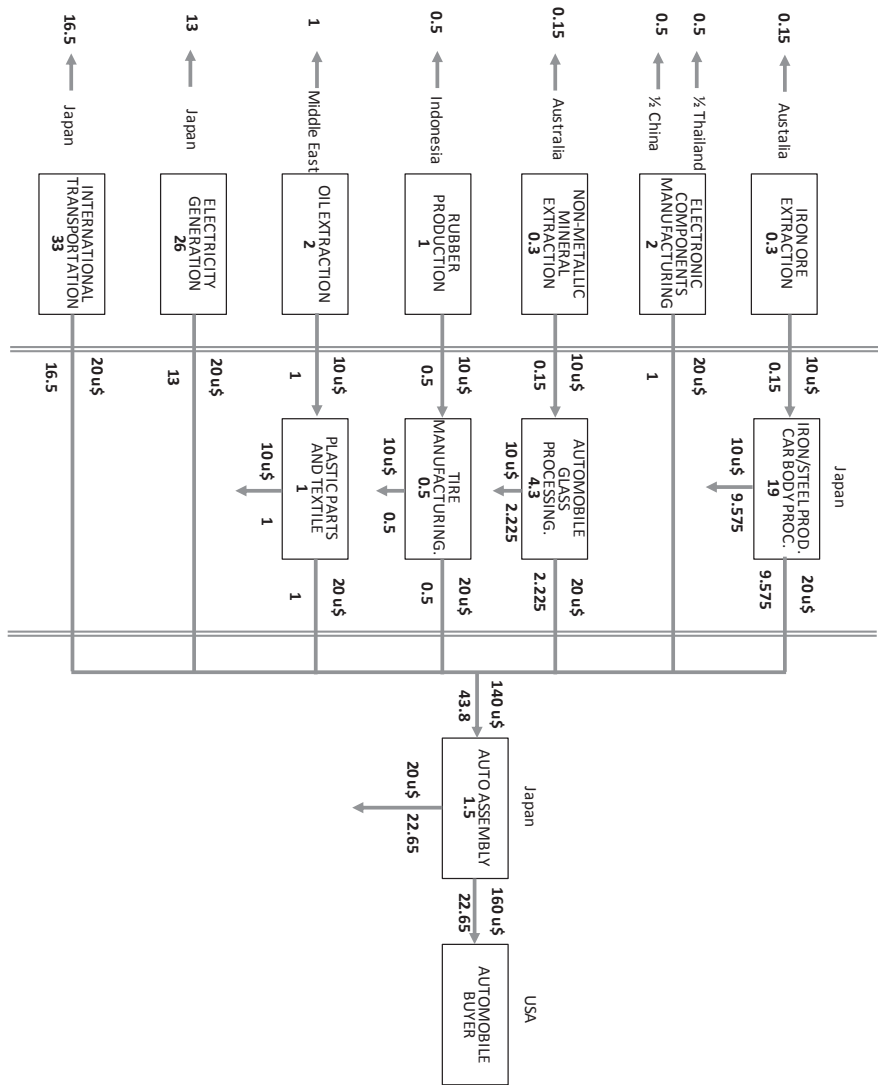
Figure 3: The downstream carbon responsibility, passed on from downstream customers to upstream suppliers in a simplified supply chain of automobile production.



By shared producer and consumer responsibility, an agent acts as both a producer and a consumer at the same time, except for those being at the very beginning of the supply chain which performs only as a producer and those being at the very

end of the supply chain which acts only as a consumer. For the example in Box 1, the iron/steel and car body producing sector is a producer which provides car body to the automobile assembly industry and at the same time a consumer which purchases iron ore from the iron ore extraction sector. In this shared producer and consumer responsibility approach, consumer responsibility is different from the consumer responsibility principle as discussed above; since here it is not only the final consumer but also intermediate consumers who assume part of the responsibility. As shown in Figure 4, if a half-half allocation is used, the iron/steel and car body producing sector (in Japan) is allocated 50% of the emissions from its direct upstream supplier, which are added to its own direct emissions and then allocates half of them down to its direct customer, the automobile assembly sector. The emissions accounted for by the iron/steel and car body producing sector is then $(0.3/2+19)/2=9.575$ units. At the same time, the iron ore extraction (in Australia) is responsible for $0.3/2=0.15$ units and the automobile assembly sector (in Japan) is responsible for 9.575 units of emissions. In the same way, two electronic components manufacturers are responsible for 0.5 units by each (Thailand and China) and pass on 1 unit to the automobile assembly industry. Non-metallic mining in Australia is responsible for 0.15 units and passes on 0.15 units to its direct downstream customer, the glass processing sector. The glass processing sector (in Japan) is then responsible for $(0.15+4.3)/2=2.225$ units and passes another 2.225 units to the automobile assembly sector. Rubber production is responsible for 0.5 units (in Indonesia) and passes on 0.5 units to the tire manufacturing sector, which is finally responsible for $(0.5+0.5)/2=0.5$ units (Japan) and passes on 0.5 units to the automobile assembly sector. Oil production is responsible for 1 unit (in the Middle East) and passes on 1 unit to the plastic and textile manufacturing sector. The plastic and textile manufacturing sector is then responsible for $(1+1)/2=1$ unit (in Japan) and passes on 1 unit to the automobile assemble sector. Electricity generation is responsible for 13 units (in Japan) and leaves another 13 units to the account of the automobile assembly sector. International transportation is responsible for 16.5 units (in Japan) and passes on another 16.5 units to the car assembly sector. The car assembly sector (in Japan) is then responsible for $[(9.575+1+2.225+0.5+1+13+16.5)+1.5]/2=22.65$ units of emissions and passes on another 22.65 units to the consumer (in the USA). For their national inventory, Australia is responsible for $0.15+0.15=0.3$ units, Thailand, China and Indonesia are responsible for 0.5 units each, Middle East countries are responsible for 1 unit, Japan is responsible for $9.575+2.225+0.5+1+22.65+13+16.5=65.45$ units and the USA is responsible for 22.65 units.

Figure 4: Shared producer and consumer responsibility based on a 50%-50% allocation



It should be noted that the 50%-50% allocation (or similar allocations such as 40%-60%, etc.) can cause inconsistency in accounting for the responsibilities assumed by the final consumers if the supply chains are arbitrarily broken up into more disaggregated stages (see Lenzen, et al., 2007 for more details), e.g. one of the sectors in the supply chain being split into two or more sectors. A solution suggested by Lenzen and his colleagues to solve this problem is to use a ratio that is independent of sector classification. Value added is such a candidate in that no matter whether a supply chain is represented in a shorter or longer fashion, total value added is always the same at the end of the chain.

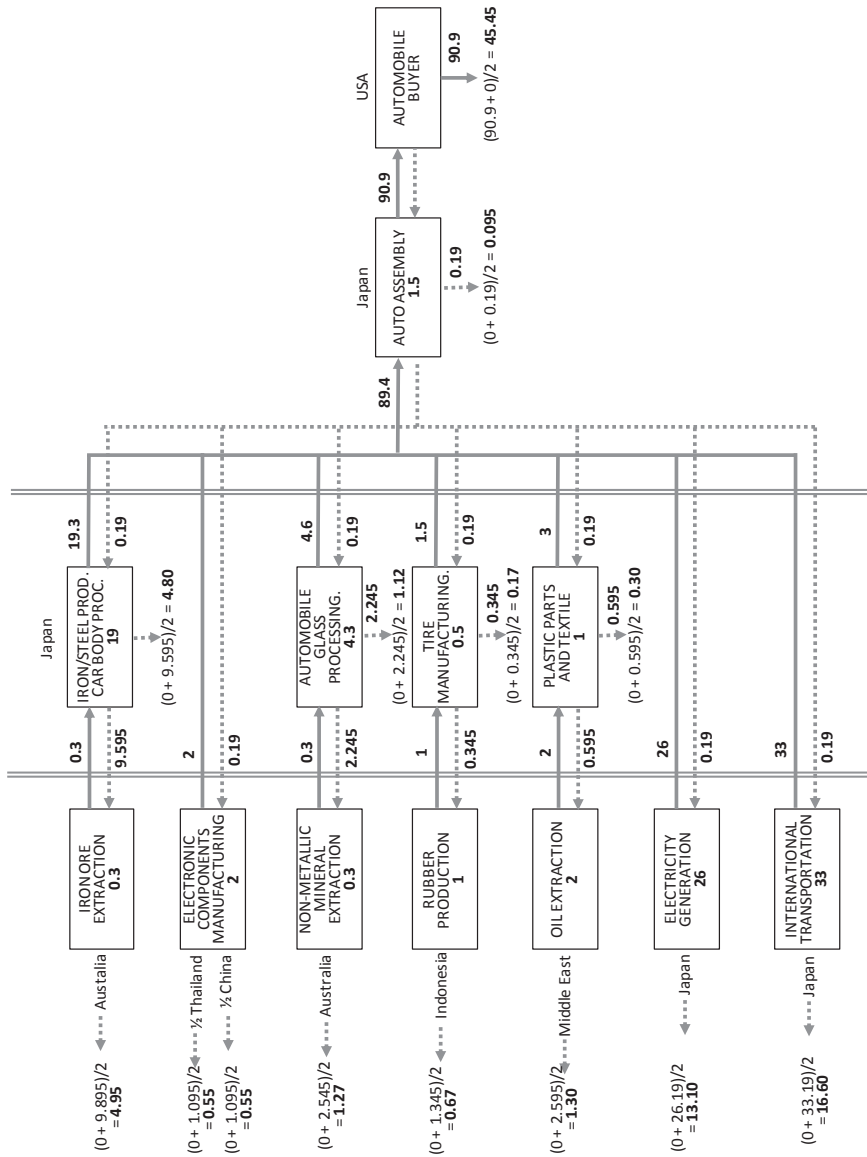
In a shared consumer and income responsibility approach, an agent assumes the responsibility as either a final consumer or a provider of primary factors, or as both. Shared consumer and income responsibility is calculated as $1/2$ consumer responsibility plus $1/2$ income responsibility for each agent. In Figure 2, we see that a buyer of the automobile in the USA, who does not provide any primary factors for this particular supply chain, holds only consumer responsibility but no income responsibility. In Figure 3, we see that the providers of primary factors for all the producing sectors in different countries along the supply chain assume income responsibilities but no consumer responsibilities since they do not consume the particular cars. So, in this supply chain, the shared consumer and income responsibility of each producing sector is $1/2$ of its income responsibilities and that of the automobile buyer in the USA is $1/2$ of its consumer responsibility. In Figure 5, we show the shared responsibility for all agents involved in the supply chain depicted in Box 1.

On the one hand, the shared consumer and income responsibility approach tries to address the whole supply chain, from the very beginning of the supply chain to the final consumer, by allocating the responsibilities among final consumers and all providers of the primary factors for the supply chain. Normally, a supply chain is a cascade of events where agents contribute in order to deliver goods to final demand. Therefore, in this type of approach, consumer responsibility is concentrated in the final consumer (Figure 2), whereas income responsibility is spread along all the providers of primary factors that contributed to the supply chain (Figure 3).

On the other hand, shared producer and consumer responsibility approach also tries to address the whole supply chain by allocating responsibilities among all agents, each of which performs as both a producer and a consumer. Typically, agents in the beginning of the supply chain will have only producer responsibilities; intermediate sectors will hold both responsibilities and final consumers will hold only consumer responsibilities (Figure 4).

The income-based responsibility principle and the consumer responsibility principle adopt a similar fashion of allocation (embodied emissions), but in opposite directions: downstream in the former case and upstream in the latter case. In the income-based responsibility scheme, downstream responsibilities will be shared among the providers of the primary factors based on their income. In particular, the providers of the primary factors for the very beginning of the supply chain will hold income responsibility for all of its own direct emissions and all downstream emissions enabled by the sector. The providers of the primary factors for an intermediate sector in the supply chain will share its own direct emissions and all downstream emissions enabled by the sector with its upstream suppliers (both direct and indirect). In the consumer responsibility scheme, all upstream responsibilities are allocated to the final consumers.

Figure 5: Shared income and consumer responsibility. The monetary fluxes are not shown but they are equal to those presented in previous figures.



The choice between shared producer and consumer responsibility or shared income and consumer responsibility will depend on the purpose of the study. The main purpose of the former is to share responsibility between firms (intermediate producers) and final consumers, whereas that of the latter is to determine the

responsibility of economic agents in their roles as either final consumers or as providers of primary inputs, or as both⁶.

Results

Using the AIO 2000, we calculate the national inventories for ten economies based on different responsibility indicators. The results are shown in Table 1.

Table 1: National inventories based on different responsibility indicators

	PRODUCER – TRADE WITH ROW			UPSTREAM EMBODIED EMISSIONS		DOWNSTREAM ENABLED EMISSIONS	
	PRODUCER	PRODUCER-EXPORTS	PRODUCER-IMPORTS	CONSUMER	EXPORTS	INCOME	IMPORTS
INDONESIA	220	182	197	137	38	210	23
MALAYSIA	102	73	83	54	29	85	19
PHILIPPINES	52	43	43	39	9	42	9
SINGAPORE	55	38	30	43	17	39	25
THAILAND	133	104	118	98	29	119	16
CHINA	2865	2523	2632	2261	342	2495	233
TAIWAN	161	118	136	108	43	151	25
KOREA	347	277	279	278	70	296	68
JAPAN	869	815	818	944	54	889	51
USA	4598	4269	4176	4481	329	4186	422
SUB-TOTAL				8442	962	8512	892
TOTAL	9404	8442	8512	9404		9404	

NOTE: In this analysis we opted to leave out international trade with the rest of the world (ROW), therefore in the computations, emissions embodied in imports and emissions generated in ROW that are enabled by exports of the ten economies to ROW are not included. For producer responsibility we have computed 3 quantities: producer, producer – exports and producer – imports. The first respects the direct emissions taking place within each country; producer – exports respects the upstream emissions embodied in exports to ROW subtracted from direct emissions; and producer – imports respects the downstream emissions enabled by imports from ROW subtracted from direct emissions. These adjustments must be done in order to compare producer with consumer and income responsibility that do not include trade with ROW. Consumer responsibility concerns emissions embodied in each country's final demand, and income responsibility concerns emissions enabled by each country's primary suppliers. The areas shaded are the values analysed in this work. For details, please refer to Rodrigues *et al.* (2006) and Zhou, *et al.* (2010).

Producer vs. consumer responsibility

Regarding the 10 economies described by the AIO 2000, we see that irrespective of the type of responsibility analysed the USA always accounts for more than

⁶ Lenzen, M. (2008). Consumer and producer environmental responsibility: A reply. *Ecological Economics*, 66, 547-550.

50% of total responsibility, followed by China with approximately 30%, and Japan with approximately 10% of total responsibility.

While producer responsibility provides information about the emissions that occur due to the production processes of a country, consumer responsibility provides information about the emissions that are generated directly and indirectly due to the final consumption of a country. For a country the difference between these two types of responsibility occurs because of international trade⁷. If a country holds a consumer responsibility higher than its producer responsibility (producer-exports in Table 1), this indicates that the emissions embodied in its imports, in order to satisfy its demand, are higher than the emissions embodied in its exports. We see that the USA, Japan, Singapore and Korea have a higher consumer responsibility than producer responsibility, whilst for the USA and Japan the difference is considerable 212 and 129 MtCO₂, for Singapore and Korea the difference is very small 5 and 1 MtCO₂ (Table 1). Nevertheless, we see that higher income countries are also those with higher differences between consumer and producer responsibilities. The USA and Japan's final demand generated more emissions than their direct emissions. In terms of climate policy, this indicates that consumption in these countries generates more emissions than the emissions that are generated within their borders. Therefore if consumer responsibility were to be applied in climate policy, these countries would have an increased responsibility. China and Indonesia are the countries where the differences between producer and consumer responsibilities are higher. This indicates that part of the direct emissions generated through production processes in these countries occur to fulfil the demand in other countries. If consumer responsibility were to be applied in climate policy, these countries would have a decreased responsibility.

Producer vs. income responsibility

As seen before, producer responsibility informs about the emissions that occur due to the production processes occurring within that country; income responsibility informs about the emissions that were directly and indirectly enabled by the providers of primary factors in exchange for an economic benefit. For a country, the differences in these quantities occur due to international trade. If a country holds an income responsibility higher than its producer responsibility (producer-imports in Table 1), this indicates that the overseas emissions enabled by its exports are higher than the emissions enabled domestically by its imports. Or in other words, that in order to generate its value added, a country enables emissions elsewhere.

Here we see (Table 2) that China and the Philippines are the only countries that have an income responsibility smaller than their producer responsibility. So, part of the emissions occurring within their borders is to provide economic benefit to the primary suppliers of other countries. Singapore and Taiwan are the

⁷ Kanemoto, K., Lenzen, M., Peters, G., Moran, D., & Geschke, A. (2012). Frameworks for comparing emissions associated with production, consumption and international trade. *Environmental Science and Technology* 46, 172-179.

countries with a highest percentage increase in their income responsibility when compared to the producer responsibility. This means, that the income of these countries depends on emissions enabled in foreign territories.

Table 2: Shared responsibility indicators

	SHARED PRODUCER AND CONSUMER	SHARED INCOME AND CONSUMER
INDONESIA	173	173
MALAYSIA	64	70
PHILIPPINES	42	41
SINGAPORE	40	41
THAILAND	103	108
CHINA	2460	2378
TAIWAN	112	129
KOREA	275	287
JAPAN	850	916
USA	4324	4334
SUB-TOTAL	8442	8477

Shared responsibility indicators

In the shared producer and consumer responsibility scenario, the direct emissions that each country generates within its borders and the emissions embodied in each country's consumption (both final and intermediate) are analysed. In the shared income and consumer responsibility, the emissions that a country enables through the provision of primary factors and the emissions embodied in its final consumption are analysed. Interestingly, we see that both shared approaches yield similar results. If we compared these results with the metric used by the Kyoto Protocol (Table 1 – Column producer-exports), in both approaches Indonesia, Malaysia, Taiwan and China have a decreased responsibility, whereas other countries have an increased responsibility. In some cases, the differences are very small, namely for Philippines, Thailand and Taiwan. Nevertheless, in the shared consumer and income approach there are bigger differences.

Conclusions

With the rapid development of emerging economies such as China and India, to tackle climate change without the participation of large developing emitters will remain very difficult and costly. Though developing countries have committed to take voluntary actions, namely nationally appropriate mitigation actions (NAMA), there is high pressure that they should commit more to quantified reductions. Many large emitters from the developing world attribute their growth to exports. They argue that emissions remain in their national inventories while the

importing countries, especially developed countries, enjoy the benefits from consumption and reduce their national inventories without necessarily making substantial efforts. As China's top climate change negotiator, Li Gao, said, China should not pay for cutting emissions caused by the high consumption of other countries. He therefore calls for a fairer agreement to address emissions embodied in international trade⁸ (BBC, 2009).

To address the problems related to producer responsibility adopted in the national inventory, we provided several alternative indicators on the basis of which we compared the national emissions by using the AIO 2000 for the case of Asian countries. Results indicate that a change from production-based accounting to other accounting principles will influence national emissions significantly. The consequences are profound for individual countries.

Though accounting for emissions related to international trade is an important issue, it is yet to be put onto the agenda of the UNFCCC for serious consideration. Several reasons can explain this. First, a change in the accounting method from production-based inventory to consumption or income-based inventory as shown in our case study, will influence the amount of emissions each country is responsible for and as a result will substantially influence quantified mitigation targets. There are both winners and losers. To reach an agreement among parties will be difficult. Second, by the consumption or income responsibility, a big political challenge is that the boundary of environmental responsibility is not consistent with the jurisdiction of a country that commits to control and limit the emissions. Third, a change from full producer responsibility to full consumer or income responsibility cannot solve the equity problem. In particular, the consumer usually has limited choices over technologies used in the production, which cause the emissions. In this sense, a shared environmental responsibility is fairer but more complicated for operation.

Regardless of the difficulties, consumption-based accounting can help address the environmental pressures caused by overconsumption and lifestyles. Through environmentally informed purchase, a cascade of demand in good environmental behaviour from the end of the supply chain to the very upstream mining activities can be formed. In addition, by the inclusion of the emissions embodied in imports, it can extend the coverage of emissions stipulated by the Kyoto Protocol and help address the carbon leakage issue. In many senses, consumption-based accounting should be taken into account by the UNFCCC as complementary information in defining national emissions responsibilities and mitigation targets.

Further readings

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This book is a primer on multi-regional input-output (MRIO) analysis. Like *The Sustainability Practitioner's Guide to Input-Output Analysis* it is written in non-technical language specifically for the non-expert sustainability practitioner.

It has been written by the world's leading experts on MRIO. It provides descriptions of seven major MRIO tools as well as case studies illustrating their application. It includes chapters on the role of MRIO analysis in global governance showing how the power and elegance of MRIO can bring new dimensions to policy making.

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"This book aims at explaining in non-technical terms how we can make sense of one of the most complex and far reaching movements of globalisation: the internationalisation of production networks. ... Many researchers are working today on modernising the statistical system in order to provide the appropriate information that will support evidence-based policy; many of them have participated in the elaboration of this book. Thus, this is a very special book: written by leading experts for the non-experts."

— Hubert Escaith, Chief Statistician, WTO

