Income-based environmental responsibility

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Abstract

Anthropogenic greenhouse gas emissions are an environmental pressure that currently arise serious concerns and that are subject to strong mitigation efforts. An allocation of the mitigation effort among multiple agents requires the prior allocation of emissions among those same agents by a metric of carbon responsibility. The metric adopted by curent climate policy is production-based (or territorial) responsibility. However, other types of responsibility have been discussed in the literature, namely consumption-based (or upstream) responsibility and downstream responsibility. In this paper we study the latter type, which is little explored in the literature, with the aim of bringing downstream responsibility to the climate policy discussion. We clarify the term through a novel nomenclature, *income-based responsibility*, we present a case-study, with the quantification of income-based responsibility for 112 world regions, and compare the results with production and consumption-based responsibilities.

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1. Introduction

In the economic process primary factors of production, such as natural resources, labor and capital, are transformed into consumption goods and services, generating externalities measured by negative environmental pressures. There is a widespread perception that the current levels of consumption and the consequent exploitation of natural resources are unsustainable, leading to environmental problems, such as the alteration of current climate patterns, scarcity of drinking water or scarcity of arable land. In order to control and minimize the externalities that result from the economic process it is necessary to quantify environmental pressures and to allocate their responsibility to the economic agents involved.

Climate change is currently ae prioritary area of environmental policy (UNEP, 2007; OECD, 2008; EEA, 2010), with a lot of attention focused on anthropogenic greenhouse gas (GHG) emissions, changing climate patterns and their potentially dangerous consequences. Many scientists believe that in order to reduce these risks a substantial reduction of GHG emissions is needed (mitigation).

The attribution of responsibility for GHG emissions is challenging, due to several characteristics of the climate change problem: it is global in its causes and consequences and its effects will only be known in the long term, raising uncertainty and risk regarding any mitigation measure (Stern, 2007). The global nature of climate change requires global action; for example if one big emitter does not commit to its responsibility and mitigation target, it is unlikely that the rest of the world can compensate for it. Moreover any emitter that stays out of any agreement will benefit from the action taken by others; mitigation efforts to cope with climate change can be considered public goods which allow for free-riding phenomena (Stern, 2007), potentially impairing or delay climate policy. The extent of global participation is essential because the higher the participation rate in any action taken, the least costly will be (OECD, 2003).

Since 1992, in the Earth Summit, international negotiations are in place seeking a global agreement for the attribution of GHG emissions' responsibility and reduction. But only in 1997 significant results were achieved, with the Kyoto Protocol. Under the Protocol each country should report, through a national GHG inventory, the 'emissions and removals taking place within national (including administered) territories and offshore areas over which the country has jurisdiction'. For the countries who ratified it, a binding target of reduction of GHG emissions was also established: 5% (on average), during the 2008-2012 period against 1990 levels (UNFCCC, 1998).

Under the Kyoto Protocol, a country should hold responsibility for all the emissions that are directly generated by the production processes that take place within its borders. This type of responsibility is often called *producer-based responsibility*, and accounts for the *direct emissions* of a country.

The geographic boundary established for GHG inventories, also used in other environmental statistics, leaves the emissions generated by international activities unaccounted for, and does not consider the transfer of emissions through international trade, enhancing the possibilities of carbon leakage (Pedersen and de Haan, 2006; Peters and Hertwich, 2008a; Peters et al., 2011) This may mean that a large fraction of emissions is not accounted or is and therefore that the responsibility of each country is not correctly determined (de Haan, 2004; Pedersen and de Haan, 2006). Moreover, the geographic boundary system is not directly comparable with macroeconomic indicators, like Gross Domestic Product (GDP), defined in the System of National Accounts (SNA) (Pedersen and de Haan, 2006; Peters and Hertwich, 2008b; UN, 2009), thus hindering the connection between environmental pressure and economic agent.

The limitations of this approach became evident when big emitters, like the USA and China, refused to ratify the Protocol or to commit to binding targets. Underlying these decisions were issues of fairness and fear of impaired competitiveness among countries (Peters and Hertwich, 2008b; Whalley and Walsh, 2009). Developing economies that are highly dependent on exports, like China and India, claim that they should not bear the responsibility for the production that they do not benefit in terms of consumption. On the other hand USA, and other developed economies, feared that their economy's competitiveness would be impaired if they had to cope with any binding target that would not also apply to developing economies. Environmental regulations can draw away investors, promoting the relocation of industries to environmental unregulated economies (pollution haven hypothesis) and enhancing any potential carbon leakage. These positions have not changed, as it could be seen in the COP15 meeting, held in Copenhagen in 2009. The Copenhagen Accord, which was supposed to be the successor of the Kyoto Protocol, does not establish binding targets, although it recognizes that a deep cut in emissions is necessary(UNFCCC, 2010).

An often suggested measure to reduce the effect of carbon leakage in a country's competitiveness are carbon-tax adjustments. This tool involves the participation of individual countries in a global scheme of emissions reduction. Participating countries lay a charge on products imported from non-participating countries, which reflects the costs in terms of carbon as if they had benn produced domestically; goods traded between participating countries would be exempt from any extra surcharge (Ismer and Neuhoff, 2004; Whalley, 2009). This mechanism would allow participating countries to be partially refunded from their carbon abatement costs, whereas non-participating countries exporting to participating countries would face an extra charge (Ismer and Neuhoff, 2004) and thus have an incentive to join the scheme. The effectiveness of carbon-tax adjustments as well as their compatibility with World Trade Organization are issues still under debate (Ismer and Neuhoff, 2004; de Cendra, 2006; Whalley, 2009).

2. Consumption-based responsibility

Consumption-based responsibility has been discussed by several authors, as an alternative to direct emissions, to name a few: Eder and Narodoslawsky (1999); Munksgaard and Pedersen (2001); Ahmad and Wyckoff (2003); Bastianoni et al. (2004); Peters and Hertwich (2008a,b); Davis and Caldeira (2010). This metric measures all the emissions generated to produce a country's final demand for goods and services. These equal the emissions generated within national territory minus domestic emissions required to generate exports plus foreign emissions required to generate imports. For a certain product, this metric takes into account all the emissions generated along its supply chain prior to the delivery to final demand; for that reason these are often called *upstream embodied emissions*.

The adoption of this type of responsibility is supported by China. Around 20% of China's emissions are generated in the production of exports, therefore China claims that a fair agreement should take into consideration that those emissions take place to produce goods that are not consumed by the Chinese people (BBC, 2009).

The boundaries of consumption-based responsibility are comparable with the System of National Accounts (SNA) (de Haan, 2004; Pedersen and de Haan, 2006), and in accordance with the System of Environmental-Economic Accounts (SEEA) (UN, 2003). Instead of using geographic boundaries, the perspective of consumption-based responsibility is based on the resident principle. According to this principle, a country is responsible for the emissions generated by the demand of its resident units. A resident unit is, according to UN (2009) 'a unit that has a center of predominant economic interest in the economic territory of that country', but might hold some economic interests abroad. This includes emissions embodied in imports but leaves out emissions embodied in exports. In fact, consumer-based responsibility is not more than a carbon trade balance as was pointed out by Rodrigues et al. (2010); Serrano and Dietzenbacher (2010).

Economic and environmental accounting evolved independently. The first is well established and widely used, whereas the second is often compiled by different entities and for different and specific purposes, therefore using a variety of concepts, methods or units. Having an environmental metric that is congruent with the SNA is important, because it facilitates comparisons, analysis and comprehension by policy makers and homogenizes the accounts allowing also for analysis through time (UN, 2003; de Haan, 2004).

Unlike what happens with production-based inventories, consumption-based responsibility accounts for the emissions generated through international activities, and minimizes the effects of carbon leakage by holding countries responsible for the emissions embodied in their trade balance (Peters and Hertwich, 2008b; Peters, 2008; Bruckner et al., 2009; Marques et al., 2011).

A measure of responsibility based on consumption is a trade related measure, that in the context of climate policy can be seen as a carbon consumption tax without being a real tax and therefore not interfering with WTO regulations (Peters, 2008). One the other hand consumption-based GHG inventories can be used to measure the carbon content of goods and services and determine a tax on consumption, like Value Added Tax, that would reflect the costs of a certain product in terms of carbon.

3. Income-based responsibility

Some authors have analyzed another metric of environmental pressure, downstream responsibility (Rodrigues et al., 2006; Lenzen et al., 2007; Rodrigues et al., 2010; Lenzen and Murray, 2010). This metric measures all the emissions required to generate a country's income through wages, profits and rents. These equal the emissions generated within national boundaries minus domestic emissions required to pay for imports plus foreign imports required to pay for exports. For a certain factor, this measure accounts for all the emissions generated downstream in its supply chain until delivery to final demand; for that reason these are often called *downstream enabled emissions*.

Downstream responsibility has never received the same discussion as its consumption-based cognate, perhaps because there is not yet a clear notion of what it means (Lenzen and Murray, 2010). A recent work by Lenzen and Murray (2010) has provided a substantial clarification of the term, by providing a match between the less known downstream-based vocabulary and the well-know consumption-based vocabulary. There are applications of the concept at the level of countries (Rodrigues et al., 2010; Lenzen and Murray, 2010; Marques et al., 2011), and at the corporate level (WBCSD and WRI, 2010; Lenzen and Murray, 2010).

The boundaries of downstream responsibility are also comparable with the SNA (de Haan, 2004; Pedersen and de Haan, 2006). The total emissions enabled by the primary supply of a country are equal to the total of emissions enabled by the various classes of primary inputs: households (mainly as receiver of wages as payments for labour), by the government (mainly as a tax collector and provider of public goods) and by capital owners (as receiver of profits). The income-based emissions of a country include the emissions enabled by the supply to the international market (exports) but does not include the emissions enabled by the demand from the international market (imports) (Rodrigues et al., 2010; Marques et al., 2011).

From a technical point of view, the accounting of income-based responsibility has the same characteristics as consumption-based responsibility. Therefore, income-based responsibility also accounts for emissions generated through international activities and can be used to minimize the effects of carbon leakage.

Whereas the use of consumption-based responsibility as a metric to levy a carbon tax would be a tax on consumption, the equivalent use of income-based responsibiliy would function as an income tax. For example, such a tax would reduce more strongly the income earned by a worker of a coal fired power plant than the income earned by a farmer. The same logic applies to countries. The income generated by a country whose main activity is oil extraction would have a higher responsibility (and thus a higher tax rate) that the income of a country whose main activity is fruit production.

A recent report by IDE-Jetro and WTO (2011) draw attention to the drastic changes that occurred in the structure of international trade in the last decades. Many products are no longer made in a single country, but instead production chains have become fragmented, with different countries specializing in specific stages of the supply chain, leading to a move from trade in goods to a trade in tasks (Hummels et al., 2001; IDE-Jetro and WTO, 2011). This shift increases the trade volume of intermediate goods, which are reexported several times during the processing stage, before reaching the country of assembly into a final good, which can itself be exported.

The emergence of global production chains changed the paradigm of international trade, from a situation in which the last step in a supply chain accounted for most added value to a situation in which it only represents a small fraction (IDE-Jetro and WTO, 2011). Under this current paradigm new statistical metrics, complementary to the traditional ones, new to be implemented in order to provide a clear view of the international trade. IDE-Jetro and WTO (2011) proposes the use of international trade through value

Responsibility	Production-based	Consumption-based	Income-based
Action	Production	Demand	Supply
Emissions	Direct	Embodied	Enabled
Direction	-	Upstream	Downstream

Table 1: Comparison between different types of approaches to GHG emissions responsibility.

added. This measure enables the correct determination of the relatiev importance of each region that takes part in a global supply chain. This report and the new framework it presents open the door for the wider application of income-based responsibility.

4. Case study

We quantified income-based responsibility for several world regions. In this Section we show the results.

4.1. Data and methodology

We used the Global Trade Analysis project database 7.1 (Narayanan and Walmsley, 2008) to build a Multi-Regional Input-Output (MRIO) model, for the year 2004. The construction process of the model using GTAP data, as well as the methodology to compute consumer-based responsibility are described elsewhere (Rodrigues et al., submitted). We have computed the income-based intensity iteratively using the following expression:

$$\mathbf{m}^{\mathbf{D}}_{\mathbf{i+1}} = \mathbf{m_L} + \hat{\mathbf{x}}^{-1}\mathbf{Z}\mathbf{m}^{\mathbf{D}}_{\mathbf{i}}, \tag{1}$$

where vectors are in column format, $\hat{}$ is diagonal matrix, $\mathbf{m^L}$ and $\mathbf{m^D}$ are the vectors of direct and downstream carbon intensity (Rodrigues et al., 2010) and $\mathbf{Z}$ and $\mathbf{x}$ are, respectively, the matrix of inter-industry transactions and the vector of total output. The initial condition is $\mathbf{m^D_0} = \mathbf{m^L}$, and converge occurs when a desired fraction of downstream emissions embodied in primary income has fell below a threshold of $1 \times 10^{-6}\%$.

4.2. Per capita and per dollar GDP carbon responsibilities

The detailed results obtained are reported in Table 2. In order to facilitate the subsequent discussion we selected 15 representative regions for which we present figures. These regions comprise individual countries and two aggregated EU regions: EUR-17 (Austria, Belgium, Cyprus, Denmark Finland, Greece, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, Sweden and United Kingdom) and EUR-10 (Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia). The latter is the group of countries that joined the European Union in 2004.

GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
AUS	Australia	315.27	305.47	376.61	19.94	637.79
NZL	New Zealand	28.34	34.30	29.45	3.99	96.44
XOC	Rest of Oceania	17.22	17.75	15.56	8.71	21.28
CHN	China	4071.13	3147.11	3450.95	1307.99	1674.13
HKG	Hong Kong	54.70	97.23	92.20	6.96	163.01
JPN	Japan	924.98	1214.09	1058.83	127.92	4658.74
KOR	South Korea	344.35	335.40	316.03	47.64	676.50
TWN	Taiwan	220.70	167.41	199.11	22.76	305.29
XEA	Rest of East Asia	75.80	57.27	65.68	25.36	25.59
KHM	Cambodia	2.81	3.71	2.19	13.80	4.88
IDN	Indonesia	295.57	261.55	307.17	220.08	254.70
LAO	Lao PDR	1.40	2.00	1.11	5.79	2.45

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
MYS	Malasya	125.32	68.91	145.18	24.89	114.90
PHL	Philippines	67.38	72.68	52.22	81.62	84.48
SGP	Singapore	38.20	58.33	46.76	4.27	106.81
THA	Thainland	192.72	144.05	148.13	63.69	161.70
VNM	Vietname	72.93	67.97	55.31	83.12	43.03
XSE	Rest of Southeast Asia	7.44	9.08	18.02	51.30	5.59
BGD	Bangladesh	28.78	41.11	25.00	139.21	55.91
IND	India	919.76	860.79	760.23	1087.12	641.26
PAK	Pakistan	111.19	126.67	88.15	154.79	94.73
LKA	Sri Lanka	10.86	15.63	9.25	20.57	20.08
XSA	Rest of South Asia	8.35	13.97	7.77	56.32	13.90
CAN	Canada	460.01	424.99	512.81	31.96	979.13
USA	United States of America	4879.14	5511.71	4650.48	295.41	11673.38
MEX	Mexico	327.08	353.65	189.41	105.70	683.24
XNA	Rest of North America	3.15	4.95	1.49	0.13	5.89
ARG	Argentina	118.20	88.41	124.44	38.37	150.40
BOL	Bolivia	8.96	8.52	9.39	9.01	8.78
BRA	Brazil	234.81	215.53	241.66	183.91	616.54
CHL	Chile	54.98	44.07	52.67	16.12	89.64
COL	Colombia	45.19	48.14	62.14	44.92	97.46
ECU	Ecuador	17.31	21.09	26.82	13.04	29.97
PRY	Paraguay	2.87	4.55	4.79	6.02	8.42
PER	Peru	25.09	30.06	27.98	27.56	68.63
URY	Uruguay	4.02	6.30	3.39	3.44	13.69
VEN	Venezuela	123.52	88.30	179.07	26.28	108.23
XSM	Rest of South America	1.86	2.37	1.23	1.39	3.52
CRI	Costa Rica	4.14	6.39	5.11	4.25	19.47
GTM	Guatemala	8.47	13.49	6.47	12.29	27.45
NIC	Nicaragua	3.51	4.56	1.85	5.38	4.39
PAN	Panama	4.87	7.86	5.24	3.18	12.60
XCA	Rest of Central America	11.00	16.51	8.51	14.07	24.15
XCB	Caribbean	142.85	139.65	89.92	38.45	193.12
AUT	Austria	52.27	82.86	68.14	8.17	292.31
BEL	Belgium	72.39	124.15	85.20	10.42	352.31
CYP	Cyprus	7.05	9.24	5.45	0.83	15.42
CZE	Czech Republic	99.41	81.15	81.68	10.23	108.03
DNK	Denmark	44.27	62.00	65.20	5.41	243.73

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
EST	Estonia	15.03	13.55	10.68	1.34	10.22
FIN	Finland	57.67	69.19	64.69	5.24	185.92
FRA	France	255.58	410.46	302.32	60.26	2046.47
DEU	Germany	599.25	804.45	733.92	82.65	2740.50
GRC	Greece	74.78	94.89	77.69	11.10	205.20
HUN	Hungary	42.71	52.20	37.33	10.12	99.65
IRL	Ireland	33.97	46.59	52.95	4.08	182.24
ITA	Italy	332.60	476.05	340.80	58.03	1677.82
LVA	Latvia	6.45	11.84	5.85	2.32	13.47
LTU	Lithuania	9.42	14.51	9.15	3.44	21.20
LUX	Luxembourg	9.73	11.25	9.83	0.45	31.86
MLT	Malta	2.73	3.43	1.56	0.40	5.32
NLD	Netherlands	165.81	172.01	155.14	16.23	578.98
POL	Poland	240.70	212.64	202.00	38.56	233.62
PRT	Portugal	50.19	64.34	45.92	10.44	167.72
SVK	Slovakia	24.67	25.91	20.51	5.40	41.55
SVN	Slovenia	12.62	13.93	12.97	1.97	32.52
ESP	Spain	266.76	324.69	258.40	42.65	1039.90
SWE	Sweden	37.41	69.97	64.65	9.01	346.41
GBR	United Kingdom	438.29	657.35	541.88	59.48	2123.60
CHE	Switzerland	26.69	72.40	59.52	7.24	357.54
NOR	Norway	52.45	46.51	143.27	4.60	250.05
XEF	Rest of EFTA	4.62	5.64	4.68	0.32	15.71
ALB	Albania	4.24	5.77	3.82	3.11	8.99
BGR	Bulgaria	41.83	31.29	32.12	7.78	24.57
BLR	Belarus	50.59	43.54	48.50	9.81	21.96
HRV	Croatia	15.20	20.30	11.58	4.54	33.93
ROU	Romania	76.53	69.01	58.11	21.79	74.42
RUS	Russian Federation	1332.95	1016.77	1464.48	143.90	569.84
UKR	Ukraine	217.62	126.61	159.47	46.99	60.98
XEE	Rest of Eastern Europe	5.89	8.15	3.05	4.22	2.60
XER	Rest of Europe	70.96	68.06	56.35	14.29	44.98
KAZ	Kazakhstan	161.61	134.85	157.05	14.84	44.35
KGZ	Kyrgyzstan	5.18	5.71	4.66	5.20	2.21
XSU	Rest of former Soviet Union	132.88	94.27	128.90	37.40	20.20
ARM	Armenia	3.38	4.29	2.47	3.03	3.34
AZE	Azerbaijan	24.18	26.86	21.59	8.35	8.73

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
GEO	Georgia	2.43	4.67	2.36	4.52	4.47
IRN	Iran	299.80	301.86	340.16	68.80	157.86
TUR	Turkey	163.34	192.71	153.30	72.22	295.83
XWS	Rest of West Asia	909.16	707.86	1235.51	118.40	691.10
EGY	Egypt	120.29	101.71	113.73	72.64	76.81
MAR	Morocco	31.86	38.01	27.92	31.02	50.25
TUN	Tunisia	18.38	18.61	14.76	10.00	27.99
XNF	Rest of Norh Africa	127.64	110.65	191.62	38.10	112.39
NGA	Nigeria	39.92	38.16	101.83	128.71	68.57
SEN	Senegal	4.15	5.91	2.24	11.39	7.20
XWF	Rest of West Africa	19.85	34.51	20.36	117.42	50.73
XCF	Rest of Central Africa	7.80	11.54	27.42	35.36	38.01
XAC	Rest of South C. Africa	9.09	14.40	37.72	71.34	23.89
ETH	Ethiopia	3.70	6.74	2.34	75.60	7.28
MDG	Madagascar	1.36	2.03	1.84	18.11	4.35
MWI	Malawi	0.55	1.57	0.63	12.61	1.79
MUS	Mauritius	1.83	3.80	2.43	1.23	5.92
MOZ	Mozambique	1.60	3.40	2.04	19.42	6.09
TZA	Tanzania	3.06	6.51	2.99	37.63	11.47
UGA	Uganda	2.26	3.51	2.90	27.82	7.27
ZMB	Zambia	1.77	3.09	2.14	11.48	5.40
ZWE	Zimbabwe	8.78	6.89	7.81	12.94	4.08
XEC	Rest of Eastern Africa	21.04	34.27	25.33	99.73	50.19
BWA	Botswana	3.76	6.38	4.53	1.77	8.72
ZAF	South Africa	329.12	213.38	312.64	47.21	213.93
XSC	Rest of SACU	3.44	6.33	4.86	4.84	9.06
		21731	21731	21731	6405	40962

Table 2: Producer, consumer and income-based responsibility of GTAP regions (year 2004) (Mt CO_2).

Figure 1 displays the per capita producer, consumer and income-based responsibilities of selected countries. The per capita normalization allows a better comparison between countries than the corresponding absolute val-

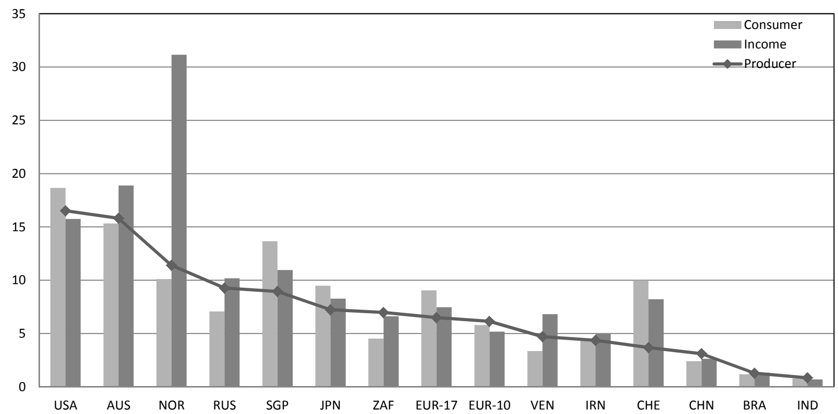

Figure 1: Per capita producer, consumer and income-based responsibilities (in ton CO_2).

ues. Per capita producer responsibility tells us how many tons of CO_2 are generated inside the country's border per inhabitant. Per capita consumer responsibility indicates how many emissions each person is responsible for as a consumer of final goods and services. Finally, income responsibility are the emissions enabled by each person as a supplier of primary inputs.

We see that citizens of wealthier economies are, on average, responsible for more CO_2 emissions than citizens from least developed economies. We also see that in wealthier regions per capita consumer responsibility is typically higher than producer responsibility. This observation indicates that, in these regions, the (upstream) carbon embodied in exports exceed the carbon embodied in exports. This phenomenon is particularly striking in small open economies, such as Singapore (SGP) or Switzerland (CHE), why rely strongly on international trade.

However, some rich economies such as Canada (CAN), Australia (AUS) and Norway (NOR) are an exceptions to this norm. These countries have per capita consumer responsibilities lower than producer responsibilities but interestingly, all exhibit an income-based responsibility that is higher than producer responsibility. This same pattern can be observed in other countries, for example Russia (RUS), South Africa (ZAF) or Venezuela (VEN). This indicates that the supply of primary inputs provided by these regions enabled the generation of emissions abroad.

A similarity between all countries mentioned in the previous paragraph is the fact that they are all fossil fuel exporters. Therefore, the interpretation of these results is straightforward. It is the export of fossil fuels that enables the occurrence of emissions abroad when the fuel is burned and the emissions take place. The rationale for income-based responsibility can be put as follows: a country who supplies fossil fuels should hold responsibility for the emissions generated downstream, because it receives money from the fuel sale. Interestingly, using this indicator we find that Norway, a country with mostly hydro-generated electricity and and a very 'clean' economy (Peters and Hertwich, 2006; Yamakawa and Peters, 2011), has the highest per-capita income-based responsibility in the world.

In Figure 2 producer, consumer and income-based GDP intensities are plotted. We find that developing economies have higher carbon intensities than more developed economies. The relations between producer, consumer

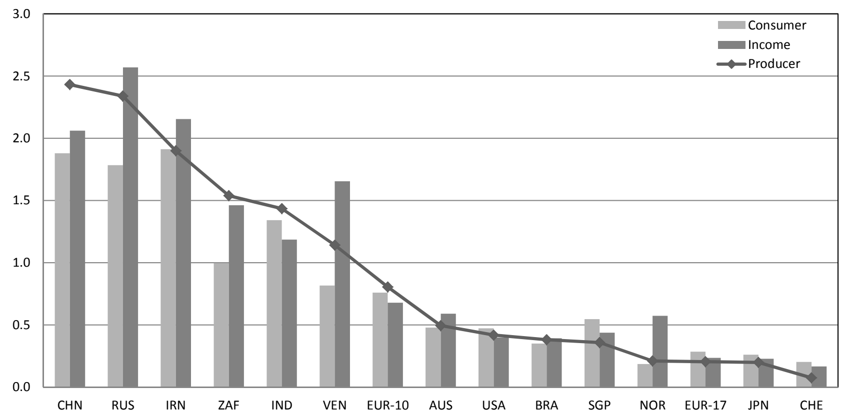

Figure 2: Per 2004 dollar GDP producer, consumer and income-based responsibilities (in ton CO_2).

and income responsibilities are maintained, in case of rich countries the differences are smoothed (for example, NOR), in case of not so wealthier countries differences are sharpened (for example, VEN).

5. Conclusions

The aim of this work is to clarify and illustrate the potential applications of the concept of downstream responsibility. We believe that the modest size of the literature and research on this topic results from the difficulty in providing a clear intuition for this metric, which in turn makes the understanding by the general public difficult.

However, we believe that this lack of intuitiveness might be a problem of nomenclature. Will the general read recognize upstream responsibility as consumer-based responsibility? Probably not. Therefore we propose the term income-based responsibility to address downstream responsibility.

To provide some illustrations of this metric we present empiricial values of income-based responsibility and compare them to the Kyoto definition of producer responsibility and the frequently used measure of consumer-based responsibility. We find that for some countries, each the responsibility metric provides very different values, while for other countries, they are all very similar.

The most emblematic case is that of Norway. This is a rich nation, seen as one of the 'cleanest' countries in the world, with low producer and consumer responsibilities. However, when it is analyzed from the point of view of the emissions enabled by its income we find that Norway is a country whose income is generated at the expense of large CO_2 emissions due to the export of fossil fuels.

If a consumer-based indicator is used, a costumer can improve his/her environmental performance through the selection of clean suppliers. An income-based indicator offers the symmetric possibility to suppliers. For example, Norway can increase its environmental performance by deciding to sell fossil fuels only to countries with carbon efficient production chains.

We hope that this paper has helped to clarify the interpretation and application scope of income-based responsibility .

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References

Ahmad, N., Wyckoff, A., 2003. Carbon Dioxide emissions embodied in international trade of goods. Technical Report DSTI/DOC(2003)15. Organization for Economic Co-operation and Development. Paris, France.

Bastianoni, S., Pulselli, F., Tiezzi, E., 2004. The problem of assigning responsibility for greenhouse emissions. Ecological Economics 49, 253–257.

BBC, 2009. China seeks exports carbon relief. http://news.bbc.co.uk/2/hi/science/nature/7947438.stm.

Bruckner, M., Polzin, C., Giljum, S., 2009. Counting CO_2 Emissions in a Globalised World. Technical Report. World Trade Organization-United Nations Environment Programme. Geneva, Switzerland.

de Cendra, J., 2006. Can emissions trading schemes be coupled with border tax adjustments? an analysis vis-à-vis wto law. Review of European Community and International Environmental Law 2, 131–145.

Davis, S., Caldeira, K., 2010. Consumption-based accounting of CO_2 emissions. Proceedings of the National Academy of Sciences 12, 5687–5692.

Eder, P., Narodoslawsky, M., 1999. What environmental pressures are a region's industries responsible for? A method analysis with descriptive indices and input-output model. Ecological Economics 3, 359–374.

EEA, 2010. The European Environment - State and Outlook 2010 Synthesis. Technical Report. Copenhagen, Denmark.

de Haan, M., 2004. Accounting for goods and for bads - Measuring environmental pressure in a national accounts framework. Ph.D. thesis. Twente University. Enschede, The Netherlands.

Hummels, D., Ishii, J., Yi, K., 2001. The nature and growth of vertical specialization in world trade. Journal of International Economics 1, 75–96.

IDE-Jetro, WTO, 2011. Trade patterns and global value chains in East Asia: From trade in goods to trade in tasks. Technical Report. IDE-JETRO, World Trade Organization. Geneva, Switzerland.

Ismer, R., Neuhoff, K., 2004. Border tax adjustments: a feasible way to address nonparticipation in emissions trading. Cambridge Working Papers in Economics CWPE 0409 Department of Applied Economics, University of Cambridge .

Lenzen, M., Murray, J., 2010. Conceptualising environmental responsibility. Ecological Economics 70, 261–270.

Lenzen, M., Murray, J., Sack, F., Wiedmann, T., 2007. Shared producer and consumer responsibility - theory and practice. Ecological Economics 61, 27–42.

Marques, A., Rodrigues, J., Domingos, T., 2011. Embodied emissions and the carbon trade balance between world regions. 19^{th} International Input-Output Conference of the International Input-Output Association .

Munksgaard, J., Pedersen, K., 2001. CO_2 accounts for open economies: producer or consumer responsibility. Energy Policy 3, 327–334.

Narayanan, B., Walmsley, T., 2008. Global trade, assitance and production: the GTAP 7 data base. Technical Report. Center for global trade analysis - Purdue University. West Lafayette, IN.

OECD, 2003. OECD environmental indicators: development, measurment and use. Technical Report. Organization for Economic Development and Cooperation, Environment Directorate. Paris, France.

OECD, 2008. OECD Key environmental indicators 2008. Technical Report. Organization for Economic Development and Cooperation, Environment Directorate. Paris, France.

Pedersen, O., de Haan, M., 2006. The system of environmental and economic accounts 2003 and the economic relevance of physical flow accounting. Journal of Industrial Ecology 1-2, 19–42.

Peters, G., 2008. From production-based to consumption-based national emissions inventories. Ecological Economics 1, 13–23.

Peters, G., Hertwich, E., 2006. Structural analysis of international trade: environmental impacts of Norway. Economic Systems Research 18, 155–181.

Peters, G., Hertwich, E., 2008a. CO_2 embodied in international trade with implications for global climate policy. Environmental Science and Technology 5, 1401–1407.

Peters, G., Hertwich, E., 2008b. Post-Kyoto greenhouse gas inventories: production versus consumption. Climate Change 1-2, 51–66.

Peters, G., Minx, J., Weber, C., Edenhofer, O., 2011. Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences .

Rodrigues, J., Domingos, T., Giljum, S., Schneider, F., 2006. Designing an indicator of environmental responsibility. Ecological Economics 59, 256–266.

Rodrigues, J., Marques, A., Domingos, T., 2010. Carbon Responsibility and Embodied Emissions: Theory and Measurement. Routledge, London, UK.

Rodrigues, J., Marques, A., Domingos, T., submitted. The GTAP database as a large sparse multi-regional input-output table. Economic Systems Research .

Serrano, M., Dietzenbacher, E., 2010. Responsibility and trade emissions balaces: An evaluation of approaches. Ecological Economics 69, 2224–2232.

Stern, N., 2007. The Economics of Climate Change - The Stern review. Cambridge University Press, Cambridge, UK.

UN, 2003. Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003. Technical Report. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank.

UN, 2009. System of National Accounts 2008. Technical Report. United Nations Statistics Division. New York, NY.

UNEP, 2007. Global Environmental Outlook - GEO4 Environment for development. Technical Report. Valletta, Malta.

UNFCCC, 1998. Kyoto Protocol to the United Nations Framework Convention on Climate Change. Technical Report. Bonn, Germany.

UNFCCC, 2010. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session. Technical Report FCCC/CP/2009/11/Add.1. United Nations Framework Convention on Climate Change. Geneva, Switzerland.

WBCSD, WRI, 2010. The Greenhouse Gas Protocol - Corporate Value Chain (Scope 3) Accounting and Reporting Standard Draft for Stakeholder Review. Technical Report. World Business Council fo Sustainable Development and World Resources Institute. Geneva, Switzerland.

Whalley, J., 2009. On the effectiveness of carbon-motivated border tax adjustments. Technical Report. Asia-Pacific Research and Training Network on Trade - Working Paper Series 63. Bangkok, Thailand.

Whalley, J., Walsh, S., 2009. Bringing the Copenhagen global climate change negotiations to conclusion. CESifo Economic Studies 55, 255–285.

Yamakawa, A., Peters, G., 2011. Structural decomposition analysis of greenhouse gas emissions in Norway 1990-2002. Economic Systems Research 23, 303–318.