Income-based environmental responsibility

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Abstract

Anthropogenic greenhouse gas emissions are an environmental pressure that currently raise 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 current 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 it to the climate policy discussion. We clarify the term through a novel nomenclature, *income-based responsibility* and present a case-study, with the quantification of income-based responsibility for 112 world regions,

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we compare the results with production and consumption-based responsibilities.
Keywords: carbon responsibility, downstream responsibility, income responsibility, multi-regional input-output analysis

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 adverse 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 responsibility for them to the economic agents involved.

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

The global nature of climate change requires global action; for example, if one large 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 delaying climate policy. The extent of global participation is essential because the higher the participation rate in any action taken, the least costly it 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, does not consider the transfer of emissions through international trade, and enables carbon leakage (Pedersen and de Haan, 2006; Peters and Hertwich, 2008a; Peters et al., 2011)

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 production from which they do not benefit in terms of consumption (BBC, 2009). On the other hand, the USA and other developed economies, fear that their economies' competitiveness will be impaired if they have to cope with any binding target that is not also applied to developing economies. Environmental regulations can draw away investors, promoting the relocation of industries to environmentally unregulated economies (the pollution haven hypothesis) and enhancing any potential carbon leakage. These positions have not changed, as 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 for reducing the effect of carbon leakage on a country's competitiveness are carbon- motivated border 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, the amount charged should reflect the cost of carbon, in terms of emissions trading, as if the goods imported were to be produced in the participating country (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 a penalty (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 the 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 responsibility based on 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 the emissions generated to produce a country's final demand for goods and services. These equal the emissions stemming from within the national territory minus the 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).

According to the principle of responsibility based on consumption, a country is responsible for the emissions generated by its final demand. This includes emissions embodied in imports but leaves out emissions embodied in exports. In fact, consumer-based responsibility is a carbon trade balance as was pointed out by Rodrigues et al. (2010); Serrano and Dietzenbacher (2010) and Kanemoto et al. (2012).

Unlike production-based inventories, consumption-based responsibility accounts for the emissions generated through international trade, 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, which 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 developed 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 the emissions required to generate a country's income through wages, profits and rents. These equal the emissions generated within national boundaries minus the domestic emissions generated downstream of imported products plus the foreign emissions generated downstream of exported products. For a certain product, this measure accounts for all the emissions generated downstream in its supply chain until delivery to final demand; for that reason Lenzen and Murray (2010) named these type of emissions *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-known 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 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 responsibility would function as an income tax. For example, such a tax would reduce more strongly the income earned by a shareholder of a coal fired power plant than the income earned by an investor through agricultural investments. 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) draws 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, need 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 of value added. This measure enables the correct determination of the relative importance of each region that takes part in a global supply chain. This report and the new framework it presents open the door for wider applications of income-based responsibility.

4. Case study

In this Section we present the results of the quantification of income-based responsibility, for 112 world regions, using the Global Trade Analysis Project (GTAP) database. We compare the results with production and consumption-based responsibilities.

4.1. Data and methodology

We used the GTAP 7.1 database (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 thoroughly elsewhere (Rodrigues et al., submitted). To quantify income-based responsibility we followed the same approach. The computation of income-based intensity was performed iteratively, since it is the fastest computation method available (Rodrigues et al., submitted), according to the following expression:

$$\mathbf{m^D_{i+1}} = \mathbf{m_L} + \hat{\mathbf{x}}^{-1}\mathbf{Z}\mathbf{m^D_i}, \qquad (1)$$

lowercase are vectors, uppercase are matrices, 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 **Z** and **x** are, respectively, the matrix of inter-industry transactions and the vector of total output. The initial condition is $\mathbf{m_0^D} = \mathbf{m^L}$, and the converge criterion occurs when a desired fraction of downstream emissions embodied in primary income has fallen 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 1. In order to facilitate the subsequent discussion we selected 15 representative regions for which we present figures. These regions are either individual countries or two aggregate 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-8 (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
MYS	Malaysia	125.32	68.91	145.18	24.89	114.90

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
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
EST	Estonia	15.03	13.55	10.68	1.34	10.22

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
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
GEO	Georgia	2.43	4.67	2.36	4.52	4.47

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GTAP code	Region's name	Producer	Consumer	Income	Pop.	GDP
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 1: 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 the selected regions. The per capita normalization allows a better comparison between countries than the corresponding absolute values. 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 the emissions that each person is responsible for as a consumer of final goods and services. Finally, income responsibility represents the emissions enabled by each person as a supplier of primary inputs.

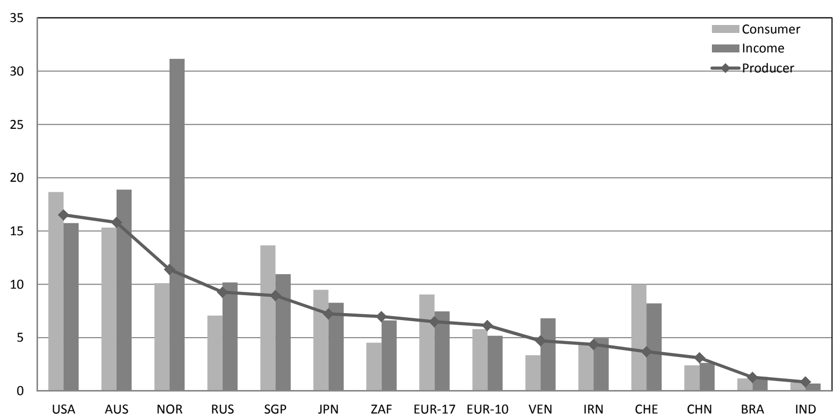

Figure 1: Per capita producer, consumer and income-based responsibilities (in ton CO_2).

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 imports exceed the carbon embodied in exports. This phenomenon is particularly striking in small open economies, such as Singapore (SGP) or Switzerland (CHE), who rely strongly on international trade. On the other hand, for bigger economies, like USA or China (CHN), the indirect measures of responsibility are closer to the direct measure due to the predominance of the domestic effects.

However, some rich economies such as Canada (CAN), Australia (AUS) and Norway (NOR) are 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), Venezuela (VEN) or Iran (IRN). 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 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 carbon intensities of GDP are plotted. We find that developing economies have higher carbon

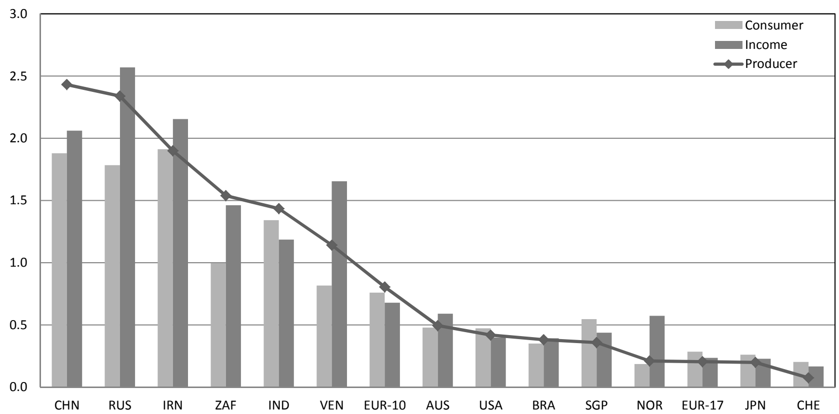

Figure 2: Per 2004 dollar GDP producer, consumer and income-based responsibilities (in ton CO_2).

intensities than more developed economies. The relations between producer, consumer 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). Brazil (BRA) appears amongst more developed economies, a exception to the pattern fins. This may be explained by the fact that this country highly relies on hydro power. In 2004, the % of domestic electricity generated from hydro power was 82.8, only surpassed by Norway (NOR) with 98.8 (IEA, 2006).

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 public recognize the term 'upstream responsibility´ as meaning ´consumption-based responsibility'? The term upstream, *per se*, indicates the direction from where carbon responsibility arrives to an agent, but it says nothing about the economic process that caused the emissions. Thus this term was replaced in the literature by a more intuitive one: consumer-based responsibility. Downstream responsibility also tell from where carbon responsibility arrives to an agent, but it also says nothing about the economic process that caused the emissions. In this case the process in question is the supply of primary inputs, to production processes, that enable emissions to occur (Table 2). Therefore downstream responsibility could be replaced by supply-based responsibility. However if we agree that responsibility should be placed on those that take some benefit from carbon emissions, supply-based responsibility is not informative regarding that benefit, whereas consumption-based responsibility is. The supply of primary inputs, to a production process involves the provision of labour (or any other primary factor of production) in return of a salary, or in a broader view an income. Therefore we propose the term income-based responsibility to address downstream responsibility.

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

Table 2: Comparison between different types of approaches to GHG emissions responsibility.

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

Another application for income-based responsibility could be its use, together with consumption-based responsibility in a single metric of shared responsibility, as proposed by some authors (Rodrigues et al., 2006; Lenzen et al., 2007).

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

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