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"Production-based versus Consumption-based approach: a literary review of the policy implications"

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I would like to thank Prof.Hannon for his support and kindness throughout my research, especially during such an unprecedented time. This paper is dedicated to the memory of my grandmother, who would have always wanted to see me graduated, and who has always been inspirational to me.

TABLE OF CONTENTS

List of figures

List of abbreviations

CBA Consumption based approach

CBAM Carbon boarder adjustment measures

CO_2 Carbon dioxide

COP Conference of Parties

ETF Enhanced Transparency Framework

ETS Emission Trading Scheme

GDP Gross domestic product

GHG Greenhouse gas emissions

IPCC Intergovernmental Panel on Climate Change

LDC Least Developed Countries

MAC Marginal Abatement Cost

NDC Nationally Determined Contributions

PBA Production based approach

SIDS Small Island Developing States

UNFCCC United Nations Framework Convention on Climate Change

Abstract

Au niveau international, la responsabilité des émissions de gaz à effet de serre est calculée sur la méthode « production-based approach » (PBA). Cette méthode est connue pour être la plus robuste car elle repose sur des données précises et elle est actuellement la base des négociations mondiales sur le climat. Le PBA tient compte des émissions générées dans le lieu où les biens ou services sont produits, attribuant ainsi la responsabilité des émissions générées uniquement au producteur. Cette approche a été largement critiquée dans une grande partie de la littérature, affirmant que ce dernier néglige le côté consommation de la comptabilité carbone. Une autre approche, basée sur la consommation, a connu un intérêt croissant, bien que rarement il a été étudié comme un remplacement complet à l'approche PBA. La « consumption-based approach » (CBA) tient compte des émissions au point de consommation, attribuant ainsi toutes les émissions générées lors de l'extraction des ressources, de l'assemblage et de la distribution au consommateur final de biens ou de services.

L'objectif de ce travail est de donner une analyse comparative des deux principales approches de comptabilisation du carbone, afin de voir s'il existe des elements dans la littérature, qui montrent une amélioration de la performance environnementale des politiques climatiques grâce à la CBA, compte tenu des relatives implications.

Introduction

The international community has been striving to find a more equitable and just strategy to allocate responsibility in order to reduce greenhouse (GHG) emissions. Justice has been one of the main discussion topics during the negotiations on climate change since the adoption of the United Nations Framework Convention on Climate Change (UNFCCC), reaching the principle of common but differentiated responsibility, that recognizes the different contributions of countries according to their capabilities, depending on their starting point and on the different impact level, when mitigating emissions.

Since the Art.12 of the Convention, signatories Parties are expected to disclose its national inventory of GHG emissions not controlled by the Montreal Protocol, divided by sources and removals by sinks. In 1997, under the Kyoto Protocol, developed countries agreed on taking legally binding emissions reduction targets for 2012, taking on historical responsibility for GHG emissions. During the Durban Platform in 2011, a roadmap was put forward that would have included mitigation commitments for all major emitters. The debate subsequently evolved to which countries should participate in mitigation efforts to what type of contributions they should undertake. Several targets featured a possible option, such as absolute, intensity or deviation from business as usual, during the Lima climate conference in 2014. Finally, in 2015 during the Paris climate conference, the net distinction between developed and developing countries was removed, with the Paris agreement being a milestone in climate negotiations, calling for action to be undertaken by all countries, even though with common but differentiated responsibilities.

During international climate negotiations, mitigation targets are exclusively based on emissions generated at the point of production, including the emissions from the combustion of fossil fuels for energy and transportation. The production-based approach (PBA) is currently the official carbon accounting approach adopted by the UNFCCC but increasing concerns about its limitations in involving emissions embodied in trade into the scope of accounting, have led to calls for a change in the accounting approach. The consumption-based approach (CBA) is by far the most popular approach in literature, indicated as an alternative or as an integration tool to the PBA. CBA accounts for the emissions linked to the consumption of a good or service, regardless of where these are produced, shifting the

entire emission burden on consumers. The CBA strand of literature finds that this approach could lead to numerous benefits, ranging from increased emissions coverage, encouragement of greener production, political acceptability, to improved equity and justice at the global level. It is also argued that such approach could help moving the community closer to the climate objective of avoiding dangerous anthropogenic climate change.

Chapter 1: Emission accounting concepts and methodologies

Starting from the Seventies, in order to understand the way air pollution evolves through time and space, and how it affects human health and the environment, data backing air emission inventories have been classified into different ways: national annual emission represented by polluting sector, or as spatially-resolved data according to sub-national levels of resolution (i.e. regions), or as time-resolved data according to sub-annual data (i.e. days). These inventories were also useful in order to monitor the efforts toward emission reduction targets and helped in identifying which emissions sources needed to be reduced the most, through the environmental legislation. The emissions collected are based on three different approaches involving different scopes and coverage; the territory, production based, and the consumption based (EEA, 2013). Since 1994, the United Nations body responsible for assessing the science related to climate change, the Intergovernmental Panel on Climate Change (IPCC), has been publishing "reporting guidelines" on standardized methodology for carbon emissions accounting (IPCC Guidelines on National Greenhouse Gas Inventories).

1.1 Carbon accounting approaches: production and consumption-based approaches.

Official inventories analyze emissions related to a given territory. Before the Paris agreement, only the developed countries of Annex I[1] were subject to the obligation of an annual publishing of their inventories, whilst developing countries could publish their inventory every six or seven years on average. Since the Paris Agreement entered into force on the 4th November 2016, all countries have to submit their emissions inventories at least every two years. Furthermore, the *National Inventory Report* provides a complete description of GHG emissions under the UNFCCC, regarding the activities which are

1 Signatory countries were listed in either Annex-I or Annex-II according to their commitments: Annex-I countries pledged to decrease the levels of GHG by around 5% compared to the 1990 levels over the 2008–2012 period. Whilst Annex-II countries, in addition to the GHG reduction objectives, were also obliged to support financially and technologically developing countries.

responsible for emission or absorption. The GHGs estimated in these inventories are carbon dioxide, methane, nitrous oxide, sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons (Brohé, 2016, p.48-49). The teams of experts, who are responsible for producing the inventory, they not only check and analyze methods, trends and activity data, but they are also in charge of quality assurance and quality control procedures in accordance with the general principles of carbon accounting previously mentioned.

The emission registers of the official inventories of Parties to the UNFCCC take exclusively into account emissions originating in the studied territory's jurisdiction or borders, the so-called t*erritory-based approach.*

The *production-based approach* (PBA) focuses on emissions resulting from a country's economic activities (resident companies and households irrespective of where geographically these activities take place, including the accounting of greenhouse gas emissions coming from oil, coal, and gas consumed within a country in the households, industrial production and electricity production sectors.). Furthermore, this reporting approach is regulated by the European legislation and is believed to have a more robust methodology (Brohé, 2016, p.1), enabling one to add up different inventories without risking of double counting and being able to compare emissions origin by producing maps.

Following the Polluter Pays Principle, emissions and resources extraction are here seen as the responsibility of the actor who operates the economic (production) process. At a national level, national statistical institutes or environmental agencies (or jointly such as the EU Member States through the European Environment Agency) typically report the emissions and resource extraction from within their country's borders. As things currently stand, the production-based approach is at the basis of international carbon accounting systems and international climate negotiations such as the Paris Agreement. It is worth noting that the different carbon accounting approaches point to different actors and related actions, thus resulting in different climate mitigation strategies (Tukker et al., 2020). Given the globalized feature of contemporary trade flows of goods, one may argue that the production-based approach is potentially prone to loopholes, given that it fails to include into its scope the emissions embodied in imported goods. As a consequence, despite being a pretty straightforward and reliable approach, it does not include for instance emissions stemming from international air and sea transportation, due to the fact that these emissions do not take place within a specific territory. According to Tukker et al. 2020, it fails to understand how production in a country drives impacts elsewhere by using exported goods, or how

consumption in a country drives impacts elsewhere using imported goods. Following this reasoning, developed countries could therefore lower their emissions by outsourcing carbon-intensive industries (here also seen as "free riders" due to their usually lax policies in terms of environmental and climate objectives), importing the related products. We are then presented with the concept of emissions embodied in trade, meaning that the production-based approach fails to involve into the scope of the analysis the actual GHG emissions of a country. In support of this argument, Davis and Caldeira (2010) found out that in 2004 23% of global CO_2 were internationally traded mostly from China and other emerging economies to developed countries. For instance, it appeared that in countries like France, United Kingdom, Austria, Sweden and Switzerland more of 30% di emissions were imported, whilst on the other hand in China 22,5% of emission were exported. This resulted in a clear demonstration of carbon leakage in the *production-based approach* due to the emissions embodied in trade, which were not included in the scope of the analysis. In the same study, Davis and Caldeira underline how a shift to a *consumption-based* (CBA) approach could help in redistributing responsibilities for emissions among producers and consumers, hence facilitating international agreement on global climate policies that is often highly challenged due to concerns over historical inequity of emissions from developing countries. However, one may also disagree with this assumption, due to the fact that it would take several methodology developments, in order to estimate accurately embodied emissions in trade. As a consequence, as things currently stand regarding the emissions embodied methodologies, this approach does not provide a realistic and straightforward path for climate negotiations.

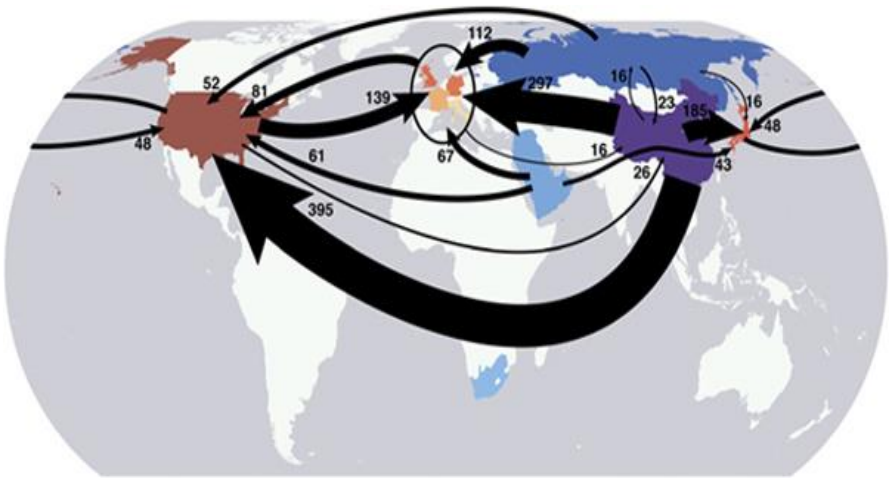

FIGURE 1. LARGEST INTERREGIONAL FLUXES OF EMISSIONS EMBODIED IN TRADE (MT CO_2 Y^{-1}) FROM DOMINANT NET EXPORTING COUNTRIES (BLUE) TO THE DOMINANT NET IMPORTING COUNTRIES (RED). SOURCE: DAVIS, S. J., AND K. CALDEIRA (2010).

An increasing number of organizations are disclosing their carbon footprints to "green" their public image (the so-called green washing phenomenon), or following a corporate social responsibility policy (Brohé, 2016, p.59). Carbon footprint is a consumption-based carbon accounting approach, meaning that instead of targeting the emissions discharged in the studied territory, this policy focuses on emissions embodied in the goods that country consumes, regardless of where goods were produced. It is argued that if industrialized countries adopted this approach, they could bring a larger amount of emissions embodied in trade from emerging countries into the scope of policy, resulting in an improvement of efficiency, cost and environmental effectiveness and in a reduction of carbon leakage on a global scale (Lininger, 2015, p.2). This means that the CBA approach is seen in the academic world as an alternative perspective to the dominant production one on carbon emissions, that considers producers of carbon emissions as fully responsible. Proponents of this approach argue that developed countries might only reduce their emissions because of these carbon leakages, and the consumption-based would therefore solve this gap.

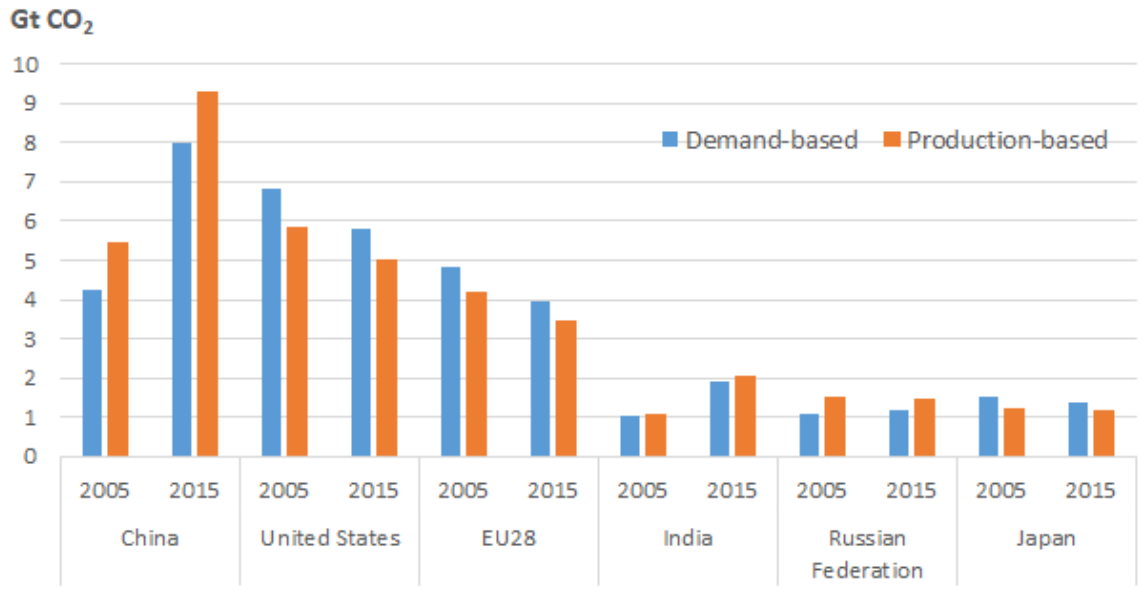

FIGURE 2. TOP 6 CARBON DIOXIDE EMITTERS, 2005 AND 2015. SOURCE: OECD (2019), CO_2 EMISSIONS EMBODIED IN INTERNATIONAL TRADE.

According to the OECD database, the the six largest producers and consumers of CO_2 emissions in 2015 (as shown above in figure 2) China, United States, European Union (EU28), India, Japan and the Russian Federation. United Stated showed a decreasing trend in production and consumption emissions since 2005, whilst there has been a significant

increase in China and India. China appears to have the highest absolute emissions from both a demand and a production perspective. It is worth noting that, even though China's per capita demand for CO_2 emissions has increased by over 75% since 2005, United States per capita demand is over three times higher.

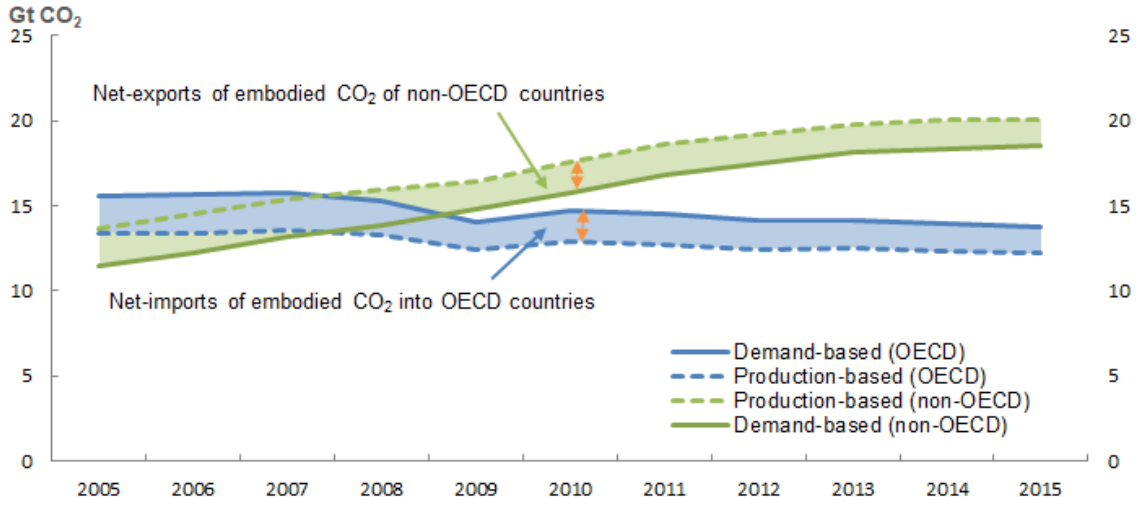

FIGURE 3. DIFFERENCE BETWEEN PRODUCTION-BASED AND DEMAND-BASED CARBON EMISSIONS, OECD VS NON-OECD COUNTRIES. SOURCE: OECD (2019), CO_2 EMISSIONS EMBODIED IN INTERNATIONAL TRADE.

As shown in the above Figure 3, the difference between production-based and demand-based carbon emissions is highlighted. While the OECD countries in total are net-importers of emissions embodied in trade (the solid blue line representing demand-based emissions is above the dashed blue line representing production-based emissions), the non-OECD countries, as a whole, are net-exporters. It is worth noting that the shaded blue area (OECD net imports) and green shaded area (non-OECD net exports) have the exact same size.

However, it should be also noted that the CBA is based on input-output matrices, involving more assumptions compared to the PBA, resulting in a less accurate analysis. On the other hand, Franzen and Mader (2018) found that for most countries the differences depending on the accounting scheme used are modest and there is no evidence for carbon leakages. More specifically, the difference between the two approaches is not driven by OECD membership or GDP per capita, instead it is greater for countries featuring high energy efficiency and import rates. As a matter of fact, they compared data available for 100 countries following the two accounting approaches, finding that carbon leakage is not confirmed by the frequency of CBA/PBA distribution. The five countries with highest ratio are almost all developing countries, except for Switzerland (where PBA accounts for 5.4 tons of CO_2 per

capita, whilst CBA accounts for 15.3 tons per capita). It is worth noticing that Switzerland mainly imports from European countries (namely Germany, Italy and France), and not from developing countries. This trend is shown even in two emblematic cases such as China (6.1 vs 7.3 tons per capita CBA vs PBA) or USA (19.2 vs 17.3 tons per capita CBA vs PBA). Whilst countries with lower ratios are quite heterogenous including Russian Federation and South Africa their study found that the difference is negligible, and it is therefore recommended to keep the *production-based* accounting approach. In support of this strand of literature, Liu (2015) argues that CBA overlooks 'in-sourcing' of polluting industries by producing regions when blaming consumers for emissions, stressing how CBA relies on data-intensive calculations and higher transaction costs than PBA. It is also explained how CBA could shift all the responsibility to consumers to put pressures on producers in order to reduce emission. Whilst ultimately it is still producers' responsibility to meet emissions reduction, possibly leading to a rebound effect in case producers might feel relinquished of responsibility about the emissions incurred by the production of their exports. However, Liu agrees on the fact that CBA could be still used as a tool to give responsibility to consumers, in order to change their habits and opt for more low-emissions products, to support producers 'sustainability efforts, and to aim at the reduction of superfluous consumption.

Another important issue pointed out is the lack of accurate and updated data from non-OECD countries that could undermine the accuracy of CBA. It is also stressed the fact that the shift to a CBA approach was mainly advocated by China in 2006, following international pressures and criticism when it became the world's largest emitter, in an effort to bring the international focus on the necessity to review the carbon accounting system and on the importance over the historical inequity of emissions. The author then concludes that a more careful use of CBA is needed, especially in the academic world, mentioning that CBA could be only considered as a supplement to the current PBA approach, but could not replace it.

In addition, Fan J. Et al. (2016) in their study agree on the view that CBA is a good supplementary to the PBA approach, but at the same time they conclude that CBA definitely alters the absolute emissions inventory and emissions shares of countries, despite not changing the PBA ranking of major emitters. In this study we are shown again China's emission as an example, comparing the two approaches and noticing that under the PBA

method China would take 24.4% of global CO_2 emissions, whilst it would take 20.8% under the CBA method. They also found that G6 countries presented with considerable differences following the PBA or CBA approaches in a range of 10% to 30%. Moreover, according to Fan J. et al, China has been enduring unfairness and that should be taken in consideration when building allocation strategies following an equity principle among countries. Furthermore, they also found that there is a considerable imbalance in the international trade between the allocation of CO_2 emissions and value added among economies. In the final part of their study, they then clearly point out that allocating emission following exclusively a production-side approach is particularly unjust especially for countries such as China and Russia. Such bold statements could be partly explained by the fact that their research project was sponsored and funded by public Chinese institutions, and particularly by the Chinese university of Mining and Technology, which can potentially have a few critical issues in this matter.

It is interesting to take in consideration a further aspect when dealing with carbon accounting approaches; the internal carbon flows within a country ("outsourcing and insourcing") and the possible role for carbon accounting approaches. Feng et al. (2013) showed in their study how the relationship between high standards of living in certain regions are often at the expenses of underdeveloped areas. Less evident is that this reasoning can be intended on a

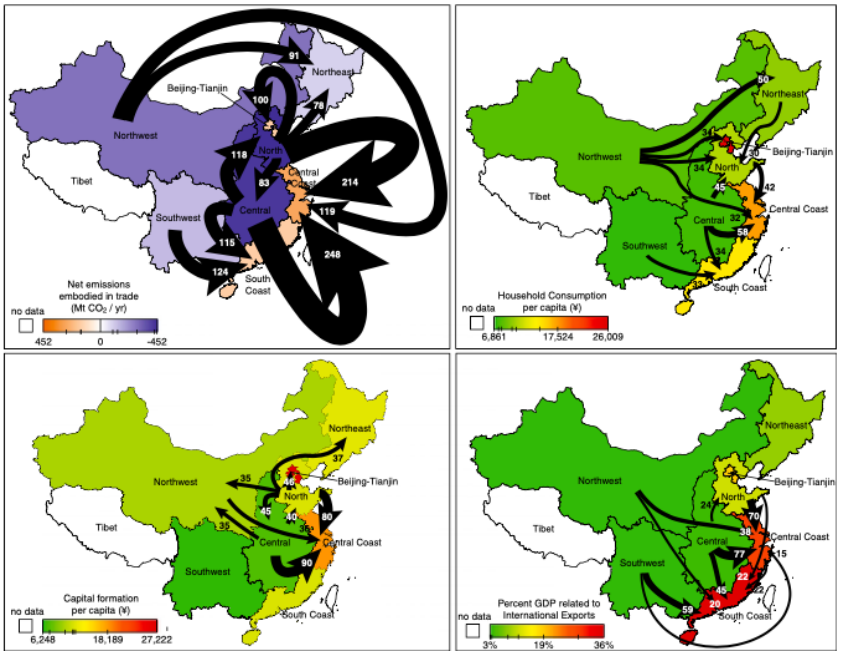

FIGURE 4. INTERPROVINCIAL FLUXES OF EMISSIONS EMBODIED IN TRADE SOURCE: FENG ET AL. (2013).

single country level. In this study Feng et al. (2013) found that 57% of China's emissions were related to goods that are consumed outside of the province where they are produced. The main carbon flows inside China being the highly developed coastal provinces (such as Beijing–Tianjin, Central Coast, and South Coast regions), importing large quantities of low value-added and carbon-intensive goods from the less developed Central, Northwest and Southwest regions. This resulting in the poorer regions struggling to meet environmental objectives, whilst the richest achieving their own by further "outsourcing". China is an emblematic example of an emerging country balancing rapid economic growth and environmental sustainability across its rapidly developing provinces. Feng et al. (2013) suggest that, in this case, CBA can contribute to a fairer and more effective policy design in order to reduce Chinese CO_2 emissions. In support of this vision, a more recent study by Wang Z. et al. (2018) confirms the presence of a considerable interprovincial transfer from the central and western regions to the eastern region, finding that the embodied carbon emissions of each province in China are increasing proportionally with the trade in each province. More specifically, inflows of embodied carbon emissions increased by 45.95%, and outflows increased by 40.36% in five years. They also state that "such huge embodied carbon emissions cannot be ignored" and they recommend applying the CBA approach that would distribute fairly the CO_2 emissions burden among the regions.

1.2 Emissions embodied in trade, PBA vs CBA: weak and strong carbon leakages

As the review of the literature presented in this paper shows, the main difference when comparing the two carbon accounting approaches lies in the fact of considering or not embodied CO_2 missions. In the *production-based* calculation, the production of energy products, goods, and services generated by the CO_2 emissions are borne by the *production-based* paradigm. In the *consumer-based* calculation, the responsibility shifts entirely to the final consumer, that is held accountable even for indirect emissions.

The strand of literature on emissions embodied in trade distinguishes in two main types of carbon leakage. When goods produced in countries with more lax environmental targets and policies are then exported to more restrictive countries, this is seen as a "*strong carbon*

leakage", meaning that this trade replacement strategy caused directly emissions in other country.

On the other hand, the emission leakage can also be seen as "*weak*", thus not directly related to the rise of emissions in another country, if we consider for instance that international specialization encourages some countries to outsource the production of carbon-intensive goods to other countries with lower production costs. Strong and weak carbon leakages result then in reallocations of CO_2 emissions, and a decrease in one country is more or less directly related to an increase in another. According to a part of the academic world (see for example Fan et al. 2016, Peters et al. 2011), *Consumption-based* accounting solve these problems, by subtracting from countries all emissions that are contained in exported products, including transportation emissions, and the embodied emissions in the inventories of the importing countries. In the case that carbon leakages are strong then the difference between *consumption-based* and *production-based* emissions might be large. Moreover, low emission countries might look less "clean" in the *consumption-based* framework and high emission countries might in reality produce goods for the living standard of low emission countries. It is evident that the difference in accountability of emissions might also have political implications. However, another strand of literature supporting PBA (i.e. Franzen A., and Mader S., 2018) also states that there is no clear evidence of carbon leakage from developed to emerging countries, considering that the data used in the CBA approach are often seen as unreliable or with a high degree of uncertainty.

1.3 Transparency and reporting obligations under the UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC) was established in response to the significant evidence of climate change in1992. According to the article 2 of the Convention, its objective is to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, allowing ecosystems to adapt naturally to climate change and ensuring global food security. Moreover, signatory parties have to adjust their national policies and measures to the mitigation of climate change, by limiting their anthropogenic emissions of greenhouse gases and protecting and enhancing their greenhouse gas sinks and reservoirs

(UNFCCC, 1992, Art.4). The Convention also acknowledges the different starting point and economic resources bases of the Parties, stating that they can implement their policies and measures jointly with others and provide assistance to other parties in order to achieve the global objective of the Convention, *"taking into account their common but differentiated responsibilities and their specific national and regional development priorities"* (UNFCCC, 1992, art.3 par. 1 and art.4 par.1).

In this context, the UNFCCC divides parties into two categories: Annex I, representing high- and middle-income countries, and Non-Annex I consisted of low and lower middle-income countries. The first reporting and monitoring system was implemented under the Convention through the Article 12. Since the Convention entered into force, every party is obliged to disclose its national inventory of GHG emissions not controlled by the Montreal Protocol, divided by sources and removals by sinks. Moreover, each developed country and others included in Annex I shall incorporate in their communication a detailed description of the policies and measures adopted to implement their commitment and an estimate of their effects on anthropogenic emissions during the period taken in consideration (UNFCCC, 1992, Art.12). Considering that the quality and accuracy of GHG inventories depends on the integrity of the methodology used and their comparability, the IPCC developed standardized requirement for reporting national inventories: the IPCC reporting guidelines require that each country of Annex I provides its annual GHG inventory (including Carbon dioxide, Methane, Nitrous oxide, Perfluorocarbons, Hydrofluorocarbons, Sulphur hexafluoride and Nitrogen trifluoride) from five sectors (energy, industrial processes and product use, agriculture, land use, land use change and forestry, waste), and for all years from the base year to two years before the inventory is due. For Annex I parties, inventory are divided in two parts: Common reporting format (CRF) with mainly quantitative information, and the National Inventory Report (NIR) containing details and description of the methodologies used and changes compared to the previous inventory. Annex I parties that are also parties under the Kyoto Protocol have to submit supplementary information with the submission of the national inventory.

In greater detail, developed countries of Annex I are required to submit their National Communication every four years, a Biennial report and a National GHG Inventory every year. On the other hand, Non-Annex I countries can submit the National Communication with flexibility almost every four years, and they are allowed as well to submit the Biennial

Update report every two years with flexibility. However, despite there has not been any substantial matter critics regarding the methodology of this MRV mechanism, this latter does not allow to involve the emissions fluxes embodied in goods into the scope of the analysis, being based on a purely territorial approach. Thanks to the Kyoto Protocol in 1997, many developed countries committed to reduce their GHG emissions. They were allowed to make use of "flexible mechanisms" to complement their domestic efforts. In this context, regulated carbon markets were established, aiming at trading carbon emissions produced by signatory Parties' projects. The Paris Agreement was signed in December 2015, representing the first universal legally binding globate climate deal. As a matter of fact, compared to the Kyoto Protocol, the Paris Agreement focuses more on consensus building, allowing for voluntary and nationally determined targets. Nationally Determined Contributions (NDCs) represent a major innovation in international climate policy. As of 2015 during the Paris Climate Conference, almost all Parties had submitted a first round of intended NDCs (INDCs), indicating their proposed contributions to halt global warming. Furthermore, unlike the Kyoto Protocol, the Paris Agreement does not provide a specific division between developed and developing nations. Throughout these changes, trading in voluntary carbon markets is expected to increase, due to an increased demand to offset unavoidable carbon emissions.

Under the Paris Agreement a new format to monitor, report and review information, the new "*enhanced transparency framework*" (ETF), was established, and includes Parties 'GHG emissions information, actions to mitigate and to adapt to the impacts of climate change, as well as the financial, technological, and capacity building support provided by developed countries to developing ones. This information must be regularly reviewed by experts to ensure its reliability. Transparency is therefore the backbone of the ETF, highlighting how Parties are committing to their pledges, building trust and confidence at the international level, and indicating whether the collective and the individual efforts undertaken by the Parties are adequate to achieve the emissions reduction targets.

The transparency "rulebook" was agreed during the COP24 in Katowice, Poland on December 2018, and builds on the existing Monitoring, Reporting, and Verification (MRV) arrangements, providing clarity on how the ETF will function. It includes two mandatory requirements on reporting, these being the GHG inventories and progress tracking of NDCs.

Developed countries must support developing countries throughout financial support, technology transfer or capacity building. Moreover, during the technical review, information provided by Parties are verified during, with the aim of building a country's capacity over time, stressing gaps or capacity building needs. During the COP24 it was also adopted a series of eight guiding principles, part of the Katowice climate package, for the modalities, procedures and guidelines of the enhanced transparency framework (UNFCC, 2020b):

1) The special disadvantaged circumstances of Least Developed and Developed Countries are acknowledged, stressing the necessity of implementing a non-intrusive and non-punitive approach, respectful of the national sovereignty.
2) The importance of improving reporting and transparency is highlighted.
3) Flexibility for developing and least developed parties is granted.
4) Transparency, accuracy, completeness, consistency and comparability as core values.
5) Avoids inefficient duplication of work.
6) Ensures that all parties keep a frequent and quality reporting.
7) Ensures that double counting is avoided.
8) Ensures environmental integrity.

Furthermore, countries can also share best practices or inform on what they are doing, promoting accountability. The exact format of information required in the ETF's Biennial Transparency Report will be decided at the end of 2020, ensuring data comparability, and will enter into force as of December 2024. Following this first step, the rulebook will be then reviewed no later than 2028. More specifically, it will include information on indicators, emissions, land-use, land-use change and forestry, international transfer of Mitigation Outcomes, and self-assessment of whether the emissions reduction target has been achieved. Each country will need to describe their methodology and accounting approach, to detail expected and achieved GHG emissions, and to report the related climate actions and policies, with this last requirement not being compulsory for developing countries. This flexibility feature aims at recognizing the difficulties of developing countries in gathering reliable data and setting up monitoring structures, whilst applying the same set of guidelines for all countries.

Parties will submit reports every two years to monitor progresses towards their NDCs, which will be considered at a collective level as an important input into the global stocktake,

strengthening climate action towards the goal of zero net emissions by 2050 and aiming at climate neutrality thereafter.

The first global stocktake will take place in 2023 and will happen every five years. Its outcome will inform the next NDC reporting cycle (UNFCC, 2020).

Box 1. Corporate Carbon Accounting

The World Business Council for Sustainable Development in cooperation with the World Resource institute (WBCSD, 2003) released a series of general principles for calculating emission allowances, these being relevance, completeness, consistency, transparency, accuracy and conservativeness.

The **relevance principle**, the quantification and reporting of carbon allowances should include only information that users need for their decision-making. Data, methods, criteria and assumptions that are misleading or that do not conform to project protocol requirements are not relevant and should not be included. Therefore, the boundaries of GHG emissions accounting and reporting should be defined appropriately according to the studied entity and the reason for GHG information gathering (Brohé, 2016, p.40).

The **completeness principle** means that all the carbon allowances effects of a project within the operational and organizational boundaries should be considered and assessed, indicating clearly whether certain sources were not reported due to lack of data or cost for data gathering.

Consistency requires that the same methods of calculation and presentation are applied to carbon allowances in such a way as that their components, criteria and assumptions used will be easily comparable.

Transparency is an essential feature in order to quantify carbon allowances. Hence, the report should be compiled, analyzed and documented in a clear and coherent manner, allowing reviewers to evaluate its credibility, and ultimately contributing to GHG emissions reduction through an objective assessment of environmental performance. In order to increase the transparency of a report, this latter should be supported by comprehensive documentation of any underlying evidence to confirm and substantiate the data, methods, criteria and assumptions used (Ortas et al. 2015)

Accuracy in data will ensure greater credibility for carbon allowances and any GHG emission reduction claim (Ortas et al. 2015). In order to improve, it is possible to adhere to the GHG calculation method and to implement good accounting and reporting system with internal and external controls (Brohé, 2016, p.41).

Conservativeness refers to the use of conservative assumptions, values and procedures when uncertainty is high, usually being prone to underestimate rather than overestimate GHG emissions reductions (Ortas et al. 2015).

Chapter 2: Evaluating policy effectiveness: Environmental-effectiveness and carbon leakage, cost-effectiveness, leakage channels, justice implications.

In this section, we will analyze the assumption that a consumption-oriented policy (if adopted by a coalition of industrialized countries) can be more effective than the production-based one. We will use cost-effectiveness, environmental effectiveness, and carbon leakage as indicators for the effectiveness of a climate policy. In the strand of the academic literature dealing with unilateral climate policy, consumption-based approach is often indicated as more effective. The main argument is that a consumption-oriented policy, pursued by a coalition of industrialized countries (e.g. by the EU or OECD countries), is potentially more effective than the current production-based approach, due to the current production and trade patterns (far higher carbon-intensity of the exports of emerging economies compared to the exports of most industrialized countries, as seen before in the study by Davis and Caldeira, 2010). As a matter of fact, the CBA would allow industrialized countries to include a larger share of global emissions than the PBA.
Furthermore, as Peters et al. (2011) found, the gap between production and consumption-based emissions has rapidly grown wider for industrialized countries, thus confirming the crucial role of this argument.

In order to compare the consumption with the production-based approach, it is necessary to fix a common feature or aspect across the two policies to allow for a meaningful analysis. Usually the most used features would involve fixing the same carbon price or the same emission reduction target in a given abating region.
As it will be shown later in the chapter, marginal abatement cost (MAC) curves are an oft-used policy tool indicating emission abatement potential and associated abatement costs, thus allowing comparison between different policies sharing a common feature. However, according to Kesicki and Strachan (2011), climate policy decisions have been often based on MAC curves with methodological shortcomings and in a simplistic manner, with not enough attention paid to the weakness of the MAC curve concept, especially when applied to crucial climate policy area sectors. Furthermore, it is argued that the abatement potential can be overestimated, whilst underestimating costs, since implementation, monitoring, and institutional costs are not integrated in the MAC curve. Nevertheless, when not relied on

exclusively, MAC curves are a useful policy tool, providing an illustrative guide for subsequent analysis especially for iterative policy making as more information on costs and policy effectiveness is discovered.

2.1 Environmental effectiveness and carbon leakage

Environmental effectiveness can be used as a criterion to compare PBA and CBA, and it is defined by the IPCC as the extent to which a policy meets its detained environmental objective. Furthermore, as Lininger (2015) puts it:

> *"As climate change is triggered by the global concentration of greenhouse gases, the appropriate environmental objective for climate policy is a reduction in global emissions and not just in emissions of a single country or a group of countries – even if the policy is pursued unilaterally."*

Environmental effectiveness is connected to some extent to carbon leakage. This latter describes a shift in carbon emissions from one region to another. According to Steininger et al. (2014), there are two main leakage concepts used in the strand of literature on emissions embodied in trade, the policy-induced (also known as strong carbon leakage) and the consumption-induced (the weak carbon leakage). The latter indicates the overall trend in the global economy that division of labor leads to more emissions embodied in goods. Policy-induced concept sees the rise in carbon emissions in a determined area as the direct consequence of more stringent and ambitious climate policies in another abating region.
On the other hand, consumption-induced leakage considers the overall trend in the global economy that division of labor (and the subsequent comparative advantage) leads to more emissions embodied in imports rather than in exports. This is the case of exports coming from emerging to industrialized economies. However, this trend is not necessarily triggered by climate policy measures, but it is rather the result of international differences in comparative advantage and the decreasing trade barriers in recent decades. Nevertheless, countries currently discussing or implementing stringent climate policies (e.g. the EU or other OECD countries) are characterized by a quite significant imbalance in their carbon embodied in foreign trade: Embodied carbon in imported goods far outweighs the embodied carbon in exported goods. This is particularly true in the case of exports from emerging to developed countries. However, it is worth noting that this trend is not necessarily caused by

climate policies, but rather reflects differences in comparative advantage and decreasing trade barriers on a global scale. Countries applying stringent climate policies (i.e. OECD countries or the EU) are usually characterized by a significant imbalance in their carbon embedded in foreign trade, with carbon embodied in goods outweighing those of exported goods (i.e. due to higher technology availability resulting in "greener" production models). As a matter of fact, a small country like Switzerland with a modestly sized industrial sector, accounts for more than double the amount of GHG emissions under a CBA than under a PBA. The same applies for countries with bigger energy-intensive industries, such as France or Austria, accounting for almost 50% more GHG emissions under the CBA scheme. Switching to a consumption-based approach by those countries, currently discussing stringent climate policies, would result in a policy base extension.

The larger the intended emissions reduction is (in the policy region), the more effective a climate policy is. On the other hand, the more significant the unintended increase in emissions is (in the non -policy region), the less effective a climate policy is. Absolute leakage is a measure of the unintended increase in emissions in relation to the emissions reduction. Therefore, if the intended emissions reduction target is the same for both policies it is possible to say that the policy with the smaller leakage ration is the one that concurs to a larger reduction in global emissions and the most environmentally effective one. This correspondence between leakage and environmental effectiveness does not stand true if policies with different reduction targets are compared.

2.2 Cost-effectiveness

Unlike environmental-effectiveness or carbon leakage that only considers the "benefits" side of a climate policy, sometimes it is preferable to consider both costs and benefits at the same time, using the criterion of cost-effectiveness. Following the cost-effectiveness policy evaluation, the best performing policy would be the one that achieves the largest global emission reduction for given global costs, or the one with least costs for a given global emissions reduction (Steininger et al. 2014). It is worth noting that when switching from a PBA to a CBA usually both costs and benefits will change, even keeping carbon prices or the emissions reductions constant in the policy region. Therefore, the policy with either the smallest leakage ratio or the largest measure of environmental effectiveness won't necessarily be the most cost-effective one.

The previous definition of cost-effectiveness was seen on the economic perspective. On the policy makers side, costs are seen as a more crucial element when they incur in their region or country when introducing the policy. However, it is evident that a policy with minimal global cost allows to achieve minimal cost at the regional level to the rest of the world.

2.3 Leakage channels (policy ineffectiveness)

In the literature, the main mechanisms for the transmission of undesired effects stemming from unilateral climate policy are classified as "leakage channels". In the so-called competitiveness channel, carbon pricing raises the costs and, as a consequence, the prices of goods produced in the policy region. Consumer or producers, needing intermediate products, will opt for cheaper substitution products, causing emission rise in the non-policy region. In the energy market channel, most GHG are produced by the burning of fossil fuels, so that abatement in one region leads to a drop in demand, and possibly to the global price of fossil fuels, in case the abating region is sufficiently large. On the other hand, other unregulated parts of the world would see an increase in demand and thus emissions will arise in other parts of the world. If we take into consideration the global income redistribution effect, that may be triggered by the introduction of an abatement policy (thus changing relative prices, demand and leakage), we are instead focusing on the income leakage channel. It might also happen that the introduction of a climate policy incentives the development of green technologies, also known as the technology spillovers channel, causing a "spillover" to the non-policy region, resulting in a drop of global emissions (Lininger, 2015). This latter is the only leakage channel to actually reduce GHG emissions, therefore in this case cost-effectiveness of a policy is enhanced. In this case, if a switch from PBA to CBA is applied, the spillover effect of green technologies also in developing and emerging countries will depend on their access to innovation facilities. As a consequence, without additional support from developed countries, the desired effect of technological innovations might not take place.

We therefore arrive to the conclusion that, for cost-effectiveness of CBA to be higher, technology availability in developing or emerging countries is a prerequisite. At the same time, if the spillover effect takes place, this latter will be enhanced by a switch to CBA, due to the fact that there will not only be ''inter-regional'', but also ''intra-regional'' spillovers

and raising the cost-effectiveness (Steininger et al. 2014). As for the intensity of the spillover effect, this will still depend on the technology facilities access.

2.4 Justice implications

If we consider the casual responsibility for emissions, consumers and producers are usually jointly "responsible" for GHG emissions. Therefore, it is not possible to reduce the discussion on GHG emissions to the simplistic dichotomy between PBA and CBA, when choosing the right target base (is it production based emissions to be reduced or consumption based ones?) and the tax base (which of the two approaches should be chosen for levying taxes?) of the climate policy.
In this context, we analyze whether any particular policy implementation would perform better in terms of fairer burden redistribution, therefore focusing on policy incidence rather than the target or tax base of a policy.
It is also evident that choosing justice as the sole criteria to opt for a determined carbon accounting approach might lead to biased evaluation and policy making (i.e. producers could opt for carbon intensive production in order to maximize gains, regardless of consumers choices).

On justice implications, Steininger et al. (2014) found that if a switch to CBA takes place through the implementation of carbon border adjustment measures (CBAM), its revenues should be channeled to developing countries in order to support their transition to sustainability, since CBAM could cause negative welfare effects on the net carbon exporting countries, shifting the global burden of climate policies on them.

Full border carbon adjustment consists of both an import tariff and an export rebate, with the tariff having a negative effect in terms of trade in the rest of the non-policy regions and the rebate compensating this effect.
As a consequence, developing and emerging countries gain from the export rebate, but suffer a welfare loss through the import tariff. Which of the two components prevails will be determined by the cost pass-through rate and the amount of emissions embodied in the imports and exports between the two regions.

For instance, if the cost-pass through rate in both regions evenly splits the tax burdens between consumers and producers, it will be the amount of carbon embodied in trade that decides which region will have welfare gains. If emerging and developing countries exports are more carbon intensive than their imports, the welfare effect of the import tariff will prevail on the export rebate effect. The non-policy region therefore suffers a welfare loss, whilst the policy region might even experience a welfare gain (beyond the environmental quality gain), if the abatement costs are smaller than the terms-of-trade gains. Whether this is verified, it depends on the actual values of the cost pass-through rate in the affected sectors. If we assume complete cost pass-through, the whole tax burden is passed on to consumers, and the welfare cost of the import tariff is completely borne by the policy-region; this would release of the burden consumers in the non-policy region, thanks to the rebate effect. This shows that, under conditions, developing countries could gain from a switch to a consumption-based policy. To conclude, there are three factors that determine the welfare net effects in a macroeconomic analysis of border carbon adjustments when implementing a consumption-based climate policy: the incidence of cost-pass through between the policy and the non-policy regions, the carbon content of the imports and exports of the two regions, the net balance between abatement costs and terms-of-trade effects.

Additionally, such a redistribution of welfare may have an effect on leakage through the income leakage channel, in the case developing and emerging economies produce and consume less, their emissions will consequently drop.

Chapter 3: Carbon accounting approaches effect on climate policies, pollution havens, border adjustment measures, mitigation strategies.

In this paper we observed the difference between the two main approaches for GHG accounting, namely PBA and CBA. One of the most important features to consider, when comparing the two approaches, is the distribution of the CO_2 emissions between trading partners. As a considerable part of the literature finds, emissions embodied in trade are a significant part of the global emissions, ranging from a 25% to a 30% of global emissions depending on the study (Zhang et al. 2017; Wang et al. 2015; Davis and Caldeira, 2010; Peters and Hertwich 2008). PBA usually gives significant advantages to the countries that outsource their emissions to some developing countries. This outcome particularly raises some objections from countries whose economy mostly relies on emission intensive exporting industries, arguing that the importers of emission-intensive goods should bear the responsibility (Dobson and Fellows 2017). The gap between embodied emissions in imports and exports is probably linked to the increasing gap between the trade volume of import and export as well as changing the trade patterns. In this chapter we discuss the impacts of PBA or CBA on climate policy design and how adopting different emissions accounting systems can lead to a subsequently different understanding, influencing climate policy discussions.

3.1 Role and impacts of the PBA and the CBA on climate policy analysis

Since the global trade volume and international integration of supply chains have been growing significantly in past decades, in combination with a decrease in international commercial barriers, it is fair to expect the emissions calculated by different approaches will also differ (Karakaya et al., 2019).

In this section, we will discuss how economics and political perspectives may change and develop on current analysis on GHG emissions, when recognizing the role of production and consumption in global emissions. Analysing the difference between CBA and PBA will show the several implications and policy considerations.

If adopted by the UNFCCC, the CBA could serve as a flexible approach to the parties and reveal trade-related emissions as well as suggest alternative mitigation policies (Amador et al. 2017). According to Dobson and Fellows (2017) argue that the adoption of the CBA, as a target base in international negotiations, may have several potential advantages, transforming the issue of the distribution of responsibility for emissions across countries into a self-enforcing situation of fair and cost-efficient global coordination, eventually improving the overall effectiveness in terms of GHG emission reductions.

As OECD puts it, when the objectives of environmental goals are clearly set and the concerned pollutants are global, measuring emissions through the CBA system is analytically the most appropriate approach to monitor and assess the impacts and policy responses (OECD 2011). This clearly matches with the objectives of climate mitigation, since GHG emissions are global pollutants and Paris Climate Agreement sets clear targets.
One of the most important aspects in order to ensure the success of post-Paris negotiations, it is to secure more ambitious reductions backed by an equitable distribution of responsibility. The Paris Agreement text clearly states that this will be achieved by periodic review, known as global stocktake. The Paris Agreement mandates that the global stocktake should be undertaken in a comprehensive and facilitative manner, in light of equity and the best available science.

Another interesting aspect regarding the account approach and its possible effects, it is the analysis in relation to the concept of decoupling (meaning that economic growth does not involve and increase level of emissions), of leakage and of the environmental Kuznets curve (EKC).
Recent studies find that carbon reduction illustrates the success of developed countries efforts in terms of decarbonization and decoupling. These achievements were considered mainly as the result of the growing deployment of renewable energy, improvements in energy efficiency, and because of structural changes in the global economy. One could argue that the monitoring of this successful result was only based on PBA, hence without accounting for CO_2 emissions embedded in exports. Therefore, we should consider that this positive outcome could also be the result of leakages (Davis and Caldeira 2010). This means

that energy-intensive manufacturing production from developed countries might have been outsourced to developing ones with relatively weak environmental regulations.

A similar strand of literature focuses on emissions and economic growth relation through the environmental Kuznets curve (EKC), which assumes that economic development in the early stages leads to a deterioration in the environment, but after a transition period, the level of economic growth increases together with a further decrease of the environmental deterioration. This assumption is not always verified in empirical evidence on growth and carbon emissions. However, Mir and Storm (2016) found that the inverted EKC curve (U shape) is particularly valid in the case of many developed countries. Again, it is worth noting that these studies are based on PBA data in their analysis. As a result, the EKC analysis could potentially reveal just the tip of the iceberg, meaning that GHG emissions are reduced as the countries become richer by outsourcing somewhere their emissions, without changing their unsustainable consumption patterns (Aşıcı and Acar 2016). As a consequence, the EKC based on the PBA data may not be reliable and would therefore require further analysis also relying on CBA data (such as for Mir and Storm, who found that, reaching the turning point in the relation between income and emissions, it requires very high income per capita and take decades for the decoupling to happen). This illustrates that the issue of delinking economic growth with emissions is still a challenge, and that it should also be considered on the CBE perspective, in order to avoid partial information on "cleaning the environment at home" whilst polluting elsewhere, thus causing GHG emissions increase at the global level. If we consider the case of a complete global agreement on GHG emissions, however, the difference between PBA and CBA approaches could be relatively irrelevant, since there would not be any possibility for carbon leakage.

3.2 Pollution havens and the convergence studies

Since some countries may implement stricter environmental policies than others, it is feared that the domestic production of dirty goods is either reduced or moved to countries with lax mitigation policies, so-called pollution havens, resulting in a loss in competitiveness for the more regulated countries. In the literature it is possible to distinguish between two main models of pollution havens.

The pollution haven effect model, which is the one with more empirical work in literature (Hille 2018), analyze to what extent the stringency of environmental policy influences economic activity. The idea at the core of this model is that environmental regulation increases the costs of key inputs for goods with carbon-intensive production, at the same time it decreases the jurisdiction's comparative advantage in those goods. Given the significant cost increases, the pollution haven effect predicts changed patterns of trade or production re-location.

The pollution haven hypothesis model claims that trade liberalization disproportionally influences trade in polluting goods and causes dirty industries to relocate to countries with weak environmental regulation. There are only little empirical work that tests the pollution haven hypothesis compared to the pollution haven effect. Overall, the results of these papers tend to be inconsistent with the pollution haven hypothesis and, therefore, provide no convincing support (Hille 2018).

A considerable part of literature started to deal with income-emissions relationship and how CO_2 emissions per capita is evolving, whether they are empirically converging or diverging. In this section we will be focusing on how relevant convergence or divergence may be to climate policy perspective in parallel with CBA-PBA discussions.

The concept of convergence studies on CO_2 emissions is based on the EKC hypothesis and income convergence, that assumes that pollution falls faster in countries with high levels of pollution, rather than in countries with lower levels. Despite being similar to the EKC curve, the convergence hypothesis that sees a change in pollution, it is not necessarily dependent on economic growth as in the case of the EKC.

If the argument of the EKC is verified, then it consequently results in a convergence in emissions between the developed and developing countries, seeing a decrease in emissions while developed countries continue to grow, and developing countries emissions will increase as they experience the first phase of economic growth (Stern 2017). On the other hand, if there is no proof of EKC for one country, the emissions may or may not converge by depending on the other factors. Some studies found that the existence of EKC for some of the countries is given by the existence of pollution heavens (Kearsley and Riddel 2010). As a matter of fact, Cole (2004) found that the existence of EKC for the North and South regions of the world is due to the outsourcing of the emissions by the North towards the South regions. Therefore, one may argue that if the empirical study finds the EKC by using the PBA data, the convergence may not hold true if CBA data are used.

3.3 Border adjustment measures

In this part we will focus on addressing consumption emissions issue under a status quo approach. Within the CBA literature there is a considerable discussion on carbon boarder adjustment mechanism (CBAMs).

In the current multilateral climate negotiations state of the art, applying border trade adjustments for both imports and exports has been seen as an alternative border tax (import tariffs or rebates on exports). Such mechanisms would essentially tax imports according to the intensity of CO_2 emissions embedded in the products, thereby avoiding a waterbed effect with domestic competitors who are subjected to firmer restrictions. Some analysts and policy makers have been strongly advocating in favor of this measures, such as the former French President Nicolas Sarkozy tabling it in 2006 (Van Asselt H. and Brewer T., (2010), Wiers J., (2008), triggering a heated discussion at the time in Europe. This possibility of adopting a carbon adjustment mechanism in the EU has been recently reconsidered by the European Commission in the framework of its objective of climate neutrality for 2050 and the Green Deal. As a matter of fact, the European Commission launched an Inception Impact Assessment[2] (IIA) on CBAMs for public review, that received over 200 feedbacks from interested stakeholders (such as NGOs, think thanks, international associations and Member States), showing the high relevance of this issue on the European agenda. Furthermore, in a motion for resolution at the European Parliament[3], pressures are being exerted in order to include CBAMs in the next Industrial Strategy that will be adopted by the European Commission, in the light of European industrial sector recovery after the pandemic crisis of Covid-19, in order to protect European industries from unfair competition and prevent carbon leakage.

As a matter of fact, one of the main points in favor of BCAMs is that countries would not have the chance to profit from a competitive advantage, because of their weaker climate policies, thus preventing free riding phenomenon, imposing higher taxes on the exports of

[2] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12228-Carbon-Border-Adjustment-Mechanism

[3] 2020/2076(INI) "A New Industrial Strategy for Europe" rapporteur MEP Calenda available at: https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/ITRE/DV/2020/05-28/1204655EN.pdf

countries, whose non-participation compromises the environmental effectiveness of the climate change policy targets.

However, on the negative side, its applicability in real world context may seem rather unfeasible, engendering negative welfare impacts and incompatibilities with established international trade norms (WTO).

Jakob et al. (2013) do not see CBAMs are an optimal policy tool to address emissions embodied in trade. In fact, they found that price changes will trigger alternative product sources, which might both increase or reduce carbon intensity of goods. Therefore, the avoidance of importing one unit of emissions does not necessarily translate into avoiding one unit of emissions into the atmosphere, but rather just changes where the emissions are emitted, which is largely dependent on the carbon intensity of production. CBAMs, in order to be environmentally effective, would need to be complemented by measures tackling the absolute volume of GHGs generated.

Another argument relating to leakage is that carbon adjustments at the border could affect country's balance of payments (Li et al. 2013), impacting on the comparative advantage of developing country exports, especially those with a high price elasticity of demand. China, for example, the world's largest exporter of emissions, could suffer substantial losses, estimated to be as 4% of its GDP. However, in order to tackle the resulting deficits, it would be needed the scaling back of imports and their substitution with domestically produced and potentially more carbon-intensive alternatives. Jakob and Marschinski (2013) refer to this phenomenon as 'consumption leakage'. This potential effect on developing countries has been referred in the literature as 'green protectionism' or 'eco-imperial- ism (Droege S. 2011).

In order to maintain stable levels of growth, developing countries should reduce the embodied emissions of their traded products, while maintaining and even enhancing their comparative advantage. It is evident that this could only be achieved if developed countries provide them financial and technological support, enabling them to achieve substantial reductions (Afionis et al. 2017). Moreover, revenues from border adjustment measures could be destined to developing countries as a means of compensation for the foregoing of exporting revenues (steinenger et al. 2014).

Following a core principle of free trade of nondiscrimination between foreign and domestic products, countries are not allowed to restrict imports on grounds of environmental impact. Therefore, the practical implementation of CBAMs depends on whether they could interfere with WTO or not, being designed in such a way as to pass the environmental effectiveness test (Afionis et al. 2017).

The Jacques Delors Insitute released a policy paper [4] on European Border Carbon Adjustment proposal tackling the question of whether it is theoretically possible to put in place WTO-compatible border adjustments in Europe. It suggests a progressive adoption of CBAMs, through a gradual phases approach, applying such measures to high potential "pilot" sectors first (such as electricity) to then apply them to other sectors, and always as a mechanism in parallel with the EU ETS.

In this way, CBAMs would be part of a system where foreign and domestic producers alike are subject to the same requirements. An alternative would be the institution of an arrangement under which trading partners are (partially) exempt, if they undertake domestic efforts that are 'comparable in effectiveness' to the border adjustment.

Lininger (2015) concludes that the only way a CBAMs could be securely put in place and pass the WTO test is not via unilateralism but through an international agreement. In the opposite case, they will only have a modest effect on the global environmental effectiveness or the cost-effectiveness of the abatement policy— if not having a negative effect.

Does it constitute a partial switch to consumption-based policy? According to Lininger (2015, p.33), CBAMs are in effect a partial switch to a consumption-based policy. In practical terms, implementing a CBA policy that achieves a full switch of the policy base is quite difficult. Therefore, despite having evidence of its possibility to implement a "full" switch in the academic world, a "partial" switch through the implementation of some sort of CBAMs may represent the most feasible option that can be realized in a real-world policy situation.

Since border carbon adjustments have never actually been implemented (at the exception of the carbon border tax in California, but not at the international level) all the academic

[4] https://institutdelors.eu/wp-content/uploads/2020/06/PP_200603_Greeningtrade3_Lamy-Pons-Leturcq_EN.pdf

knowledge is based on *ex ante* analysis. In the leakage literature, border adjustments are usually seen as one of possible countermeasures to halt leakage and losses in competitiveness, the other measures being free allocation of emissions permits and direct subsidies to affected industries. As Lininger clearly states, there is no unanimity in the academic world, whether border adjustments could help reaching these objectives (Lininger 2015 p.70).

3.4 Mitigation strategies based on PBA and CBA

Despite some criticism coming from a strand of literature, the production-based approach is still considered as the most reliable GHG accounting approach, identifying the main direct emitters. Following the polluter pays principle, such emitters are expected to reduce emissions, by investing in greener technologies, using renewable energy, enhancing energy efficiency, reducing emission factors (e.g. by fuel switching, or carbon capture, storage and usage). In the case this cannot be achieved in a cost-neutral manner, as Tukker et al. (2020) puts it:

> *"Policy has to provide a level playing field, so that even if the actor cannot finance the costs from own profit or value added, that actor can pass costs on to other actors in the value chain, since competitors have to implement similar stringent mitigation measures at probably similar costs."*

An important limitation of the production-based approach is that it does not take in consideration the influence an actor could exercise over its supply chain and related emissions, or the emissions enabled by products produced outside of the downstream chain. On the other hand, CBA helps final or intermediate consumers to identify the impacts in the supply chains of their purchases. Typical mitigation options highlighted by this approach could be that actors could try to help suppliers to improve their environmental performance or shift to low-impact suppliers of the same (final or intermediate) products. Otherwise, actors could also shift expenditure to alternative low impact products or services that provide a similar functionality, avoiding high impact supply chains products and shifting expenditure to low-impact products and related activities. Finally, actors could simply reduce purchases of products overall (Tukker et al. 2020), relying on the environmental

footprint of products (e.g. via labelling), although this may not always be realistically feasible. At the same time, users of intermediate goods have less freedom, since they need such intermediate inputs for the production of other materials, products or services. They can only change inputs if the process or product design is changed, and inputs are driven by the level of production. An important limitation of the CBA is that it neglects the downstream life cycle impacts of this material and product output.

As previously mentioned in this paper, most of the current climate mitigation policies adopt territorial-based regulations, taking the PBA perspective. Therefore, in some strand of the literature, there has been the need to ensure a more equitable transition to a low-carbon future, that current PB policies alone are not adequate to achieve, limiting global emissions (Scott et al. 2016).

If CBA perspective is considered in policymaking as a main accounting system, then the policy should specifically focus on household consumption patterns and international trade (Hubacek 2016), requiring relevant knowledge, infrastructure, and resources to change household behavior towards low-carbon society (Brizga et al. 2017).

As Scott (2016) states:

> *"when consumption and trade-related emissions are targeted, policymakers become more likely to adopt more comprehensive policies, as it becomes more essential to accompany a set of policy mechanisms addressing demand, trade, and business supply chains*."

In this respect, in addition to current PBA perspectives, new policies such as eco-labelling and consumption tax on carbon contents will get increasingly important when attention is given to domestic consumption.

Setting up sustainability targets and monitoring their progress through indicators are particularly important with respect to policy response. In this regard, emission indicators calculated with production perspective is insufficient and needs CB approach alongside for environmental performance analysis, since it is a more convenient way of measuring sustainability, considering both the direct and indirect impacts of consumption. Finally, another argument in support of CBA adoption, it is that it could be as complementary to the PBA, setting up more specific and focused emission indicators for a better understanding of

the dynamic changes of CO_2 emissions and providing the necessary information for policy making (Scott and Barrett 2015). However, a generalized approach for CBA does not seem still available to the current state of policy negotiations, since CBA still lacks methodological standards (such as the IPCC guidelines for the PBA) that would allow an extensive application of the approach at the global level.

Conclusion

In the current globalized trade, featuring a complex network of supply chains, production processes and a delocalized consumption, emissions and trade flows have been extensively studied in literature, in an attempt to find a robust and fair emission accounting approach. The two main ones, PBA and CBA, created two separate strands in the academic literature, with a few authors placing themselves in a halfway position, calling for an integrated PBA and CBA approach. In this paper we reviewed many studies in order to define the two approaches, stressing their strong and weak points as emerged from the literature, and according to the main policy evaluation parameters. Finally, we dealt with the practical implications stemming from each of the two approaches. From the studies taken in consideration in this paper, CBA approach resulted as a relatively new approach, with no "real life" policy implementations, and with only a few theoretical studies analyzing its potential as a full alternative to the PBA approach. On the more practical side, the main issue here is that CBA would require a global consensus on shifting completely emissions responsibility, currently advocated by net exporters of emissions such as China, whilst no international standard has been recognized at the international level (unlike the IPCC Guidelines for PBA), and no reliable data and inventory are currently available. In addition, in a situation where LDCs are still struggling to comply with the current GHG emissions reports, CBA could probably lead to further bureaucratic burdens and the impossibility for them to assess the national emissions due to lack of technological and financial means. Furthermore, the CBA approach has been also considered as a tool to improve PBA emissions accounting accuracy, adding the consumption perspective to the scope of the approach. In this context, carbon board adjustment measures have been considered as a way of leveling the playing field between countries with more stringent climate policies and the so-called free riders, or countries with lax climate regulations. The European Union is starting to show some interest in this manner, but still a lot of issues seem to be in the way of its implementation, such as, among others, its incompatibility with WTO rules, that do not allow mechanisms to favor domestic goods over imported goods of the same kind. Therefore, it is still to be seen, in both the academic world and on the practical implementation side, whether CBA could be a more accurate approach than PBA, improving the environmental effectiveness of climate policies, or it will eventually be overcome due to

its unfeasibility and complexity. To conclude, PBA still stand as the most reliable GHG accounting approach in the short and medium terms. However, the new emission burden related issues will also need to be addressed, but, as things currently stand, it is not clear how and whether they will be tackled.

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