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Toward Consumption-Based GHG Emissions Accounting: From Calculation to Policy-Making

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Abstract

In national carbon emissions reduction targets as well as within the international climate change regime, production-based (or territorial) emissions are taken into account. Such accounting imposes the major responsibility for emissions on leading emerging economies where most of the carbon-intensive industries are allocated. It also provokes carbon leakage: stringent climate policies in one jurisdiction may lead to the reallocation of production and corresponding emissions to others where companies bear lower regulation costs. Consequently, asymmetry occurs. While most developed countries gradually reduce their emissions, they are simultaneously growing in emerging economies, with no significant progress in the mitigation of global climate change.

This paper directs attention to an alternative way of emissions accounting – based on consumption. In this regard, emissions are attributed to the particular economy if they are embodied in goods consumed there regardless of where exactly these emissions are generated. This type of accounting supposes that emissions of major emerging economies are not their own choice but also the reflection of the international division of labour and the result of demand for carbon-intensive goods coming from major centres of consumption in developed countries. Regular calculation and disclosure of consumption-based emissions (along with production-based ones) and their gradual integration into the process of emissions reduction target- setting would provide a new perspective on sharing responsibility for emissions, prevent carbon leakage and clearly demonstrate the need for international climate cooperation between exporters and importers of carbon-intensive goods, expand the scope of emissions under regulation, and give opportunities to countries to use the wider range of decarbonization tools. The latter would include those that involve the population in mitigation efforts and better link the price for carbon with the level of household consumption, which is important for coping with carbon inequality and promoting climate justice.

Keywords: emissions accounting, consumption-based emissions, carbon leakage, responsibility sharing, emissions embodied in trade, climate mitigation policy

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Introduction

Global greenhouse gas (GHG) emissions are rising. The Intergovernmental Panel on Climate Change (IPCC) suggests that, compared to 2010 and 1990, they increased by 12% and 54%, respectively, in 2019. Carbon dioxide (CO_2) emissions, which are mainly driven by fossil fuel combustion and industrial processes [IPCC, 2023], represent the largest share and growth in GHG emissions. Therefore, global efforts to reduce CO_2 emissions and tackle climate change continue to pose a significant challenge, and more ambitious emission reduction targets, further acceleration of the energy transition, and deeper resource efficiency improvements are urgently required at the global level to move the world toward a more secure and sustainable future. In this regard, an accurate determination of emissions that each country adds to the atmosphere is of utmost importance for a clearer understanding of how parties should share the responsibility for reducing emissions, for a precise assessment of the success or failure of climate policies that have been implemented in any jurisdiction, for the design and implementation of appropriate climate policy instruments, and for an accurate evaluation of how well or poorly a country performs in terms of emissions in comparison to others [Chen et al., 2018].

At the international level, countries measure and report their emissions using the production-based accounting (PBA) framework. This approach, as expected, has a significant effect on all discussions within the international community about general principles of mitigation, constructing agreements, sharing responsibility, or providing financial support. At the national level, production-based emissions (PBE) are also a commonly used metric measuring the ambitiousness of climate policies and their effectiveness in achieving national emission reduction targets. Since the early 1990s when the United Nations Framework Convention on Climate Change (UNFCCC) was adopted, reduction of PBE has been the most important and legally binding indicator in both national and international climate change regimes. This commonly-used, production-based perspective ignores trade-related emissions, which are now estimated to account for about 25% of global emissions. Therefore, under the PBA framework, it is impossible to determine whether these emissions are due to domestic or foreign demand [WTO, 2021]. To address this deficiency and broaden our understanding of emissions, there is an increasing recognition of the importance of consumption-based emissions (CBE). Compared to PBE, CBE better represents a country's overall carbon footprint and the role of trade, consumer demand, and global supply chains in driving emissions. In this respect, it is considered that a deeper comprehension of the role that CBE plays in promoting sustainable development and mitigating climate change, the calculation and disclosure of CBE along with PBE, and their gradual integration into the process of setting emissions reduction targets may offer some critical insights into such issues as responsibility sharing, preventing carbon leakage, expanding the scope of emissions regulation, and choice of optimal climate policy tools (Kanemoto et al., 2014; Davis, Caldeira, 2010; Chen et al., 2018; Steininger et al., 2018; Domingos, Zafrilla, López, 2016].

The primary objective of this article is to examine the important role that CBE plays when designing climate policies, particularly in meeting global climate mitigation targets, and to provide some policy proposals in that line. To that purpose, we first present the PBA and CBA approaches and reveal their similarities and differences. Second, we underline why CBE is as important as PBE, with a specific emphasis on its role in responsibility sharing, carbon leakage, sectoral emissions, and the expansion of climate policy options. Third, based on these discussions, we present some policy proposals that emphasize the critical importance of CBE from a variety of viewpoints.

The remainder of the article is structured as follows. The two primary methods of emission accounting (PBA and CBA) are comparatively introduced, followed by a discussion of the challenges arising due to the narrow focus on PBA only. Policy recommendations are offered, followed by conclusions and discussion with a special focus on the role of BRICS countries in promoting CBA.

PBA versus CBA

There are primarily two approaches to measuring emissions. The first is the PBA approach; it considers emissions generated within a specific territory or jurisdiction.[1] This emission accounting approach is directly associated with where goods and services are produced. Therefore, it is not concerned with whether goods or services (and emissions associated with them) are consumed domestically or exported to another country, and only deals with emissions that occur at the production level. The second is the consumption-based accounting

[1] The difference between territorial-based accounting (TBA) and production-based accounting (PBA) is frequently ignored in the literature. But they refer to two distinct definitions. The TBA approach does not include emissions from international activities like shipping, aviation, or tourism, and allocates them to individual countries, but the PBA framework does [Barrett et al., 2013; Hertwich, Wood, 2018; Grubb et al., 2022; Karstensen et al., 2018]. Following the literature, we will also ignore this distinction in this article and use the "production-based" term throughout the text, if a specific distinction is not needed.

(CBA) approach. According to this approach, regardless of where a good is produced, emissions associated with a product are added to the inventory of the country where it is consumed. In this regard, CBA considers the possibility of differences in geographical locations between where a good is produced and where it is consumed, and thus provides a trade-adjusted measurement of emissions [Karstensen, Peters, Andrew, 2018].

The definitional considerations of PBA and CBA demonstrate that these two emission accounting approaches differ from one another depending on how they treat emissions embodied in trade. While the PBA framework includes emissions embodied in exports (EEE) but excludes emissions embodied in imports (EEI), the CBA approach does the opposite, meaning that it excludes EEE but includes EEI. The difference between PBE and CBE thus refers to the net emissions embodied in trade (NEET=EEE-EEI) [Ghosh, Agarwal, 2014; Davis, Caldeira, 2010; Grubb et al., 2022; Domingos, Zafrilla, López, 2016], It is clear that the total (global) PBE is equal to the total CBE by formulation, yet the distribution of these emissions among countries is expected to be different. While some countries have positive NEET, others have negative ones.[2]

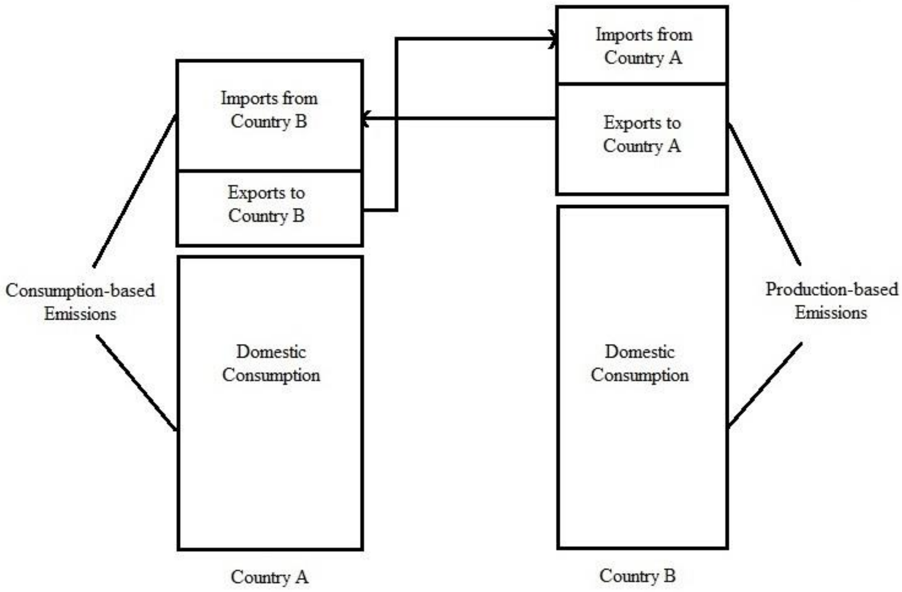

Fig. 1. Emission Accounting Concepts

Source: Authors' own illustration. Adapted from [Steininger et al., 2014; Steininger et al., 2018].

The example of two countries trading with one another (Country A and B) may help illustrate the relationship between these two concepts (PBE and CBE). This is presented in Figure 1. As shown, while Country A's CBE includes emissions from domestic consumption and emissions released in the production of its imports but not its exports, Country B's PBE includes emissions generated on its territory for both domestic consumption and exports to Country A. Therefore, exports from Country A to Country B (or imports to Country B from Country A) are included in the CBE of Country B, but vice versa for exports from Country B to Country A [Steininger et al., 2014; Steininger et al., 2018].

Given that the primary factor defining the difference between these two emission accounting approaches is international trade, understanding global supply chains and their corresponding emissions is crucial for interpreting the discrepancies between PBE and CBE. In this context, environmentally extended input-output analysis (EE-IOA) has a long history of use in academic literature as well as among international organizations, such as the Organisation for Economic Co-operation and Development (OECD). The growing interest in this subject over time resulted in new EE-IOA-based models, such as single-region input-output (SRIO) and multi-region input-output (MRIO) models, as well as databases, such as the Global Trade Analysis Project (GTAP), EXIOBASE, Eora, and the World Input-Output Database (WIOD), for the purpose of calculating emissions embodied in trade [Wiedmann, 2009; Inomata, Owen, 2014; Moran, Wood, 2014; Steininger et al., 2018].[3] These databases provide data sufficient to estimate PBE, CBE, EEE, and EEI for countries of the world.

[2] This has been illustrated by recent data in Figure 2 and Table 1.

[3] This topic is beyond the scope of this article. For further information, please see T. Wiedmann [2009] and Tukker and Dietzenbacher [2013].

Challenges

How to share the burden of emissions reduction across countries is one of the most contentious issues in international climate change negotiations. It is challenging for several reasons. Due to their long history of industrialization and fossil fuel use, developed countries, for instance, have historically been accountable for a considerable portion of GHG emissions. On the other hand, while developing countries have contributed less to global emissions, their emissions are rising now due to their rapid economic growth and will take an increasingly larger share in the future, which makes it crucial to reduce emissions in these countries. In a similar vein, while some countries, notably developed ones, may prioritize environmental concerns over economic growth, others, developing ones, have too many unsolved development problems or may largely rely on fossil fuels to meet their energy needs and/or sustain their income level. At the same time, the economic capability of developing countries—such as financial resources, technological development, capacities, and infrastructure—that could be used to effectively support their efforts to reduce carbon emissions may not be sufficient. As a result, the sharing of responsibility between countries for climate change mitigation is a complex and politically sensitive issue that requires consideration of multiple factors [Page, 2008; Peters, 2008; Ringius, Torvanger, Underal, 2002; Wei et al., 2012; Füssel, 2010; Romanovskaya and Federici, 2019].

The divergence between PBE and CBE observed at the individual country level creates another significant factor for responsibility sharing that should be critically considered. PBE has served as a commonly-used indicator for countries to report their GHG emissions under international climate change agreements since the early 1990s, when the United Nations Framework Convention on Climate Change (UNFCCC) was adopted. In this respect, PBE plays a crucial role in directing global climate negotiations, setting emission reduction goals, shaping the formulation of policy, and tracking advancement on both the global and national levels. However, emerging economies often argue that they should not be held solely responsible for the emissions associated with their exports (consider the example depicted in Figure 1) because they are mostly driven by global demand and meet the consumption needs of developed countries. They build on the opinion that those who benefit from a process should be accountable (at least in part) for the associated emissions. Therefore, it is alleged that PBE and the climate policy guided by it do not reflect emerging economies' own choices; rather, it reflects the global division of labour and imposes the major responsibility for emissions on leading emerging economies where most of the carbon-intensive industries have been allocated [Davis and Caldeira, 2010; Chen et al., 2018; Grubb et al., 2022; Karakaya, Yilmaz, Alatas, 2019; Jakob, 2021]. Figures 2 and 3 and Table 1 support these arguments between net emission exporter and importer countries and illustrate the challenge in allocating responsibility more fairly.

Figure 2 shows the difference between production-based and consumption-based CO_2 emissions (emissions embodied in trade) for some selected countries and aggregates in 2020 (more detailed information is also provided in Table 1). As can be seen, developed countries, including the U.S., Germany, and the UK, as well as some aggregates, such as the OECD and the European Union (EU), have negative NEET, indicating that these countries tend to import more carbon emissions than they export (EEI is higher than EEE). For some countries like Switzerland or Sweden, CBE are dramatically higher than PBE. The contrary is shown for emerging economies, such as India, South Africa, Russia, China, Iran, Brazil, non-OECD, BRICS5 and BRICS.[4] As shown, NEET is positive for them, implying that they are net exporters of CO_2 emissions.

[4] The BRICS consists of 10 countries: Brazil, Russia, India, China, and South Africa (BRICS5) + Egypt, Ethiopia, Iran, Saudi Arabia, and the United Arab Emirates, which joined BRICS in January 2024.

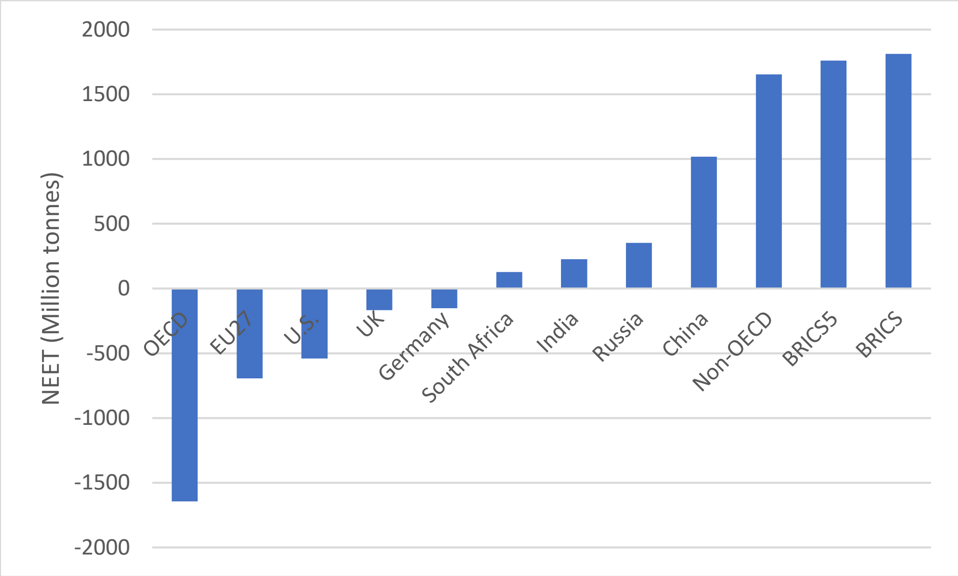

Fig. 2. Net Exports of CO_2 Emissions Embodied in Trade in Large Countries and Country Groups 2021

Source: Authors' own illustration based on the Global Carbon Budget [Friedlingstein et al., 2023].

Table 1. PBE and CBE in OECD and BRICS Countries in 2021

Country	PBE	CBE	NEET	NEET/PBE	Country	PBE	CBE	NEET	NEET/PBE
U.S.	5040.45	5581.30	-540.84	-10.7%	**Brazil**	498.02	462.98	35.04	7.0%
Japan	1063.87	1226.92	-163.05	-15.3%	**Russia**	1714.80	1362.00	352.79	20.6%
Germany	679.91	831.87	-151.96	-22.3%	**India**	2678.60	2451.73	226.87	8.5%
France	307.28	416.51	-109.23	-35.5%	**China**	11354.80	10336.99	1017.81	9.0%
Italy	337.78	434.20	-96.41	-28.5%	**S. Africa**	426.32	298.20	128.12	30.1%
UK	348.03	514.24	-166.21	-47.8%	**Egypt**	247.29	265.69	-18.40	-7.4%
Canada	538.05	502.82	35.23	6.5%	**Ethiopia**	18.95	22.69	-3.73	-19.7%
Australia	387.24	338.86	48.38	12.5%	**Iran**	689.20	620.02	69.18	10.0%
Netherlands	140.14	164.46	-24.32	-17.4%	**S. Arabia**	632.47	623.10	9.37	1.5%
Spain	230.65	272.63	-41.98	-18.2%	**UAE**	237.64	241.55	-3.91	-1.6%
R. Korea	617.08	690.28	-73.19	-11.9%					
Sweden	38.59	68.27	-29.68	-76.9%					
Switzerland	35.85	118.87	-83.02	-231.6%					
Poland	331.62	318.08	13.54	4.1%					
Türkiye	453.44	422.64	30.81	6.8%					
Mexico	469.56	507.07	-37.51	-8.0%					
Other OECD	800.64	1055.96	-255.32	-31.9%	**BRICS5**	16672.54	14911.91	1760.63	10.6%
OECD	11820.18	13464.96	-1644.78	-13.9%	**BRICS**	18498.09	16684.96	1813.13	9.8%

Fig. 3. depicts the contribution of the OECD (black line), BRICS (light gray line), and BRICS+ (gray line) countries to global emissions in terms of PBE (solid line) and CBE (dashed line) for the years 1990 to 2021. As can be seen, the OECD consistently has a higher global share of CBE than PBE. The BRICS countries, on the other hand, follow the opposite pattern. Therefore, it is clearly evident that under the current mitigation responsibility allocation approach and mitigation target setting that is purely directed by the PBE framework, developed countries receive more credit than emerging countries.

Source: Authors' own calculations based on the Global Carbon Project [Friedlingstein et al., 2023].

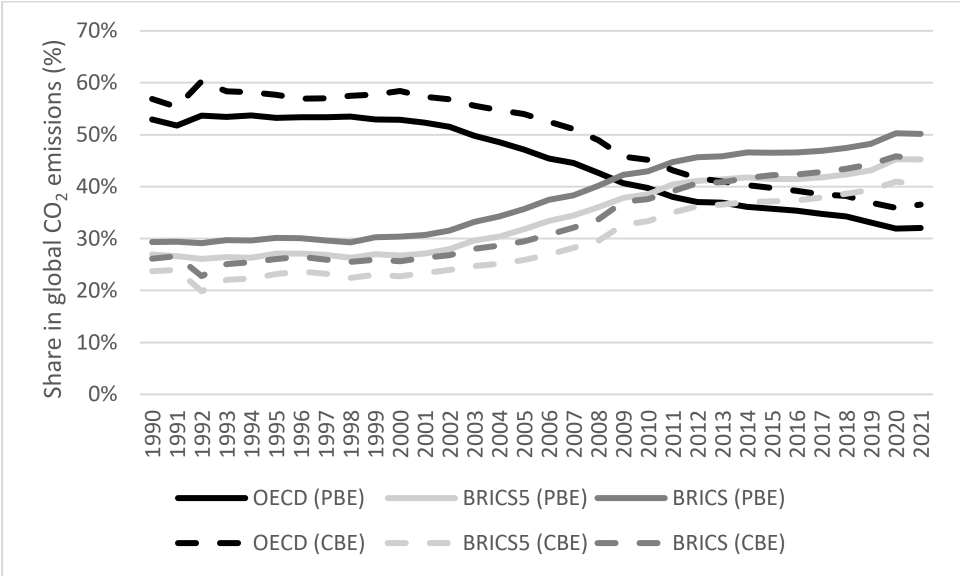

Fig. 3. PBE and CBE in the OECD and BRICS Countries (1990–2021)

*Source***:** Authors' own illustration based on the Global Carbon Budget [Friedlingstein et al., 2023].

Another important implication of the difference between PBE and CBE concerns carbon leakage. This term refers to a situation in which reducing emissions in one jurisdiction results in a rise in emissions in another jurisdiction, without an actual reduction in emissions on a global scale. Carbon leakage occurs due to uneven climate policies and results in a shift in emissions from the most constrained countries to "pollution havens", that is, to countries with laxer policies. In this regard, carbon leakage significantly reduces the overall effectiveness of global emission reduction efforts if climate policies are not implemented consistently and similarly across countries [Jakob, 2021; Meng et al., 2023].

The difference between PBE and CBE sheds light on the issue of carbon leakage by highlighting the role of international trade and emissions transfers between countries. For example, as also discussed above, when a country's CBE is high but its PBE is relatively lower, it suggests that this country is importing emissions-intensive goods and services from abroad. This indicates that the emissions associated with meeting the consumption demands are being transferred to other countries, that is, there is a channel through which carbon leaks. In this regard, considering the net emission transfers via international trade, especially from developing to developed countries, some studies argue that the stabilization of emissions in advanced countries may be partially due to growing imports from emerging and developing countries. For instance, G. P. Peters et al. [2011] demonstrated that from 1990 to 2008, net emission transfers from non-Annex B to Annex B[5] countries increased by 17% annually, and that the majority of industrialized countries increased their consumption-based emissions faster than their territorial emissions. G. Atkinson et al. [2011] showed that emerging and developing countries tend to be large net exporters of emissions. K. Kanemoto et al. [2014] also found that when adjusted for trade, developed-country emissions are increasing rather than decreasing, raising concerns that trade might undermine national carbon reduction targets. R. Wood et al. [2020] also verified Peters et al. [2011], Atkinson et al. [2011], and Kanemoto et al. [2014], revealing the increasing trend in net emission transfers from non-OECD members to OECD members from 1970 to 2006. In other words, developed countries decarbonized domestically at the expense of increased emissions in developing countries.[6]

The magnitude of carbon leakage has been extensively studied in the literature. Depending on the types of models (computable general equilibrium or partial equilibrium models) and their assumptions, the results drastically diverge from one another [Carbone and Rivers, 2017; Antoci et al., 2021; Assogbavi, Dées, 2023]. A meta-analysis of 25 studies based on 310 estimates of the carbon leakage ratio, which is simply defined as changes in emissions in the rest of the world as a percentage of domestic emissions reduction, demonstrates that carbon leakage ranges between 5% and 25% without policy and 5% and 15% with border carbon adjustments [Branger, Quirion, 2014].

[5] Annex B of the Kyoto Protocol includes developed countries and those with economies in transition that take quantitative commitments to reduce GHG emissions according to this agreement.

[6] At the same time, R. Wood et al. [2020] revealed the stabilization of emissions imports to the EU since 2008.

One frequently studied area of empirical literature on carbon leakage is the European Union Emissions Trading System (EU ETS), which is the first major carbon market in the world. The findings indicate a clear consensus on associated carbon leakage. H. Naegele and Zaklan [2019] found no evidence that the EU ETS had induced carbon leakage in European manufacturing sectors. However, it is equally important to note that this conclusion may be driven by the low carbon prices that persisted in the EU ETS during the analyzed periods, as noted by A. Antoci et al. [2021], and results may change if carbon prices rise with increasing ambitious reduction targets.[7] In this regard, for example, it is important that more recent country-specific studies seem to find some evidence of carbon leakage [Borghesi, Franco, Marin, 2020].

The difference between PBE and CBE at the sectoral level also yields some critical insights and challenges. This is because, even though these two emission accounting approaches are almost identical in some sectors, the disparity between them greatly widens in others. For example, for such sectors as households, services, or construction, which produce non-tradable goods, PBE and CBE are closer to one another. Yet, they significantly differ from each other for manufacturing, mining, or agriculture, which produce goods that are intensively traded internationally. Some studies strongly confirm this argument. J. Karstensen et al. [2018] show that imported emissions experienced a large increase from 1990 to 2006 in the EU countries, which is mainly caused by imports from non-Annex B countries. When seen from a sectoral perspective, this rise is mostly caused by energy and non-energy intensive manufacturing from China, such as chemicals, rubber, and plastic products, as well as mining activities, primarily oil from Russia and Kazakhstan. In a similar vein, Wood et al. [2020], again for the EU member countries, demonstrate that 79% (mining), 45% (manufacturing), and 37% (agriculture) of emissions resulting from European consumption take place outside of the EU. On a net-basis, 75%, 29%, and 25% of embodied carbon from mining, agriculture, and manufacturing are imported. For Japan, Z. Xu et al. [2022] find that CBE is larger than PBE and the industrial sector is the primary source explaining the gap between them.

These arguments and empirical evidence clearly reveal that the discrepancies between PBE and CBE are determined by some specific sectors. Countries cannot completely avoid this overall imbalance between PBE and CBE, especially for mining and agriculture activities, the geography of which most strongly depends on natural resources allocation. Therefore, concerns regarding competitiveness and carbon leakage are more closely related to a number of energy-intensive or trade-exposed industries, such as cement, aluminum, iron, or steel, other than agriculture, mining, or services [Grubb et al., 2022; Marcu et al., 2013; Cosbey et al., 2019; Antoci et al., 2021; Naegele, Zaklan, 2019].[8] This is also confirmed by some studies. For example, P. Quirion and Demailly [2008] investigated the carbon leakage ratio for the cement, steel, aluminum, and electricity sectors in the EU27 using the partial equilibrium model. The results revealed that the carbon leakage ratio of the EU ETS is low at the aggregate level, around 8%. However, at the sectoral level, it significantly differs depending on the sectors, for example, the EU steel sector has the highest carbon leakage rates ranging around 45%. In a similar vein, J. P. Ponssard and Walker [2008] found that an increase in non-EU imports could feasibly offset more than 70% of the decrease in EU cement sector emissions. R. Aichele and Felbermayr [2013; 2015] found strong evidence for carbon leakage and that some sectors, such as basic metals, are more prone to carbon leakage than others.

Some other factors might also potentially further widen the gap between PBE and CBE in the industry sector,[9] such as the stranded asset problem, technical and economic dependencies, high energy requirements, or price competition [Bataille et al., 2018; Bataille, 2020; Allwood et al., 2010; Tautorat et al., 2023]. For example, strong carbon lock-in stemming from the intensive fossil fuel-dependent industrial production systems, large industrial production facilities that are heavily dependent on infrastructure designed to operate for long terms, long technical lifetimes of the main components of current industrial production systems, huge sunk cost of the existing infrastructure and equipment in the case of refurbishment, increasing competition, and growing global integration in terms of ownership and value chain explain why industrial emissions are high and are expected to continue to rise unless radical shifts are made to the ways that materials are produced, consumed, and disposed of.

[7] H. Naegele and Zaklan [2019] discussed the reasons why carbon leakage is not always obvious in practice, such as due to small share of emission cost in total material cost, fixed relocation costs, or free emission allowances.

[8] In order to prevent it, most ETSs have included provisions for carbon leakage, which have a substantial impact on how well the ETS works. Accurate assessment of the potential effects of ETS is, therefore, essential for a deeper comprehension of its environmental, economic, and social effects [Marcu et al., 2013; Cosbey et al., 2019]. For example, if measures to confront carbon leakage are insufficient, emission outsourcing increases, lowering the environmental effectiveness of ETSs and their capacity to reduce emissions. If the carbon leakage provisions are generous, for example, in the form of free allocations of allowances to leakage-prone industries, it may diminish incentives to reduce emissions [Antoci et al., 2021; Jakob, 2021].

[9] Fossil fuels globally continue to be the primary source of energy for industrial activities. Without considering indirect emissions from electricity, this sector is accountable for roughly 25% of global emissions in 2021. Additionally, subsectors of the industrial sector, including iron and steel, non-ferrous metals, cement, or chemicals, are primarily responsible for a significant part of the industrial emissions [IEA, 2020].

These challenges demonstrate that focusing merely on production-related emissions while disregarding carbon outflows and inflows that occur in trade makes it difficult to both decarbonize the economy and reduce emissions globally.

Policy

How much do countries contribute to global emissions, and how efficiently do they design their policies to address climate change? The answers to these two critical questions depend on the approach to GHG emissions accounting. Simple use of PBA, as also advanced by A. Kander et al. [2015], may lead to conditions where mitigation efforts are not rewarded or actions that lead to an increase in emissions are not penalized.

As discussed above, with the rise in global trade and complex supply chains between countries, deeper domestic decarbonization, particularly in some carbon-intensive sectors, or stricter climate policies in some developed countries for climate change mitigation at the expense of higher emissions in developing countries and many other factors, the difference between countries' PBE and CBE has become increasingly pronounced over time and is expected to increase in the near future [Wood et al., 2020]. Therefore, any target-setting and policy-making that is solely based on the PBA, as is currently the case in the international climate change regime and in the national climate policies of the majority of the countries, narrow the focus, ignoring the complex relationship between emissions and trade and thus undermine the effectiveness of climate change mitigation efforts.

Nevertheless, CBA and PBA are not substitutes for one another, but complements. Relying solely on the CBA approach might be as misleading as considering only the PBA for policy-making. This is because both approaches offer some crucial insights into various elements of emissions and their sources, allowing policymakers to design more robust and efficient strategies for mitigating climate change. In this regard, PBA and CBA should be taken into account simultaneously when developing climate policies because neither fully satisfies the basic principle of "penalizing the polluter-rewarding the reduction" of. Kander et al. [2015] For instance, it is evident from the discussions on pollution havens or carbon leakage that PBA tends to credit the countries outsourcing their emissions through international trade and global supply chains. In this case, without a significant contribution to global emissions reduction, the home country is rewarded since its PBE decreases. In a similar vein, as the CBA framework, by formulation, excludes emissions embodied in exports, any decrease in emissions from the exporting activities is not reflected in CBE [Dietzenbacher, Cazcarro, Arto, 2020; Domingos, Zafrilla, López, 2016; Jakob, 2021].

Given the discussions above, the CBA approach can enable us to design more robust and efficient strategies for mitigating climate change when taken together with (not instead of) PBA.

It is often claimed that CBA is less intuitively clear and that the calculation of CBE is more challenging than of PBE. As CBE lacks a long history of institutionalized measurement and disclosure, PBE is more accessible than CBE due to its availability in many different data sources, which facilitates the widespread use of PBA in academic literature and climate change-related policy-making. However, as trade models and EE-IOA techniques have advanced significantly over the last decade, the lack of data is gradually becoming less of a problem for the implementation of CBA. Moreover, it is quite feasible now to consider not only consumption footprints related to GHG emissions, but also footprints related to water use, pollution, and biodiversity loss. Therefore, discussions on CBE are not only limited to themselves but also trigger new debates about how to better calculate footprints other than emissions and open up new spaces for developing better indicators and designing better environmental policies.

Discussions stressing the relevance of the CBA approach in formulating climate policy can be based on four essential pillars.

The first concerns sharing responsibility. As discussed previously, the current application of the "polluter pays" principle places producers, not consumers, in the primary position of responsibility for emissions reduction. For instance, China and India are frequently held accountable for a significant part of global emissions. Yet, a substantial part of these emissions is generated in the production of exported goods, and thus was produced to meet the demand of other countries. Therefore, it is not fair to attribute all these emissions to China and India, which are mainly caused by the global division of labour. In this regard, the idea of "consumer pays" based on the CBA approach is not less fair. It partly or wholly allocates the burden for reducing emissions to the country where goods are ultimately consumed [Peters, Hertwich, 2008; Sudmant et al., 2018].

The use of CBA together with PBA allows for efficient sharing of responsibility for emissions embodied in international trade between exporters and importers. Concrete ways for sharing this responsibility may differ. For example, the technology-adjusted CBE proposed by Kander et al. [2015] improves CBA by accounting for variations in carbon efficiency in export sectors among different countries to solve the issue of carbon intensity in exports. This approach considers the fact that the same product can have various emission intensities depending on the technology and manufacturing methods used in different countries. Thus, by applying technology adjustments, it accounts for these variations and provides a more precise estimate of the emissions embodied in traded goods: this makes it possible to separate the "objective" carbon intensity that arises from international labour division from "subjective" carbon intensity which is the result of domestic policies.[10] Similar attempts have been advanced by other scholars as well [Steininger et al., 2014]. For instance, A. Marques et al. [2012] compared production- and consumption-based responsibility with the income-based approach for emission reduction, arguing that those who benefit more economically (in terms of consumer/producer surplus) from a trade flow should bear greater responsibility for corresponding emissions.

Regardless of the exact algorithm, the use of CBA together with PBA for allocation of responsibility for emissions embodied in trade may practically promote cleaner production in the export sector (as discussed earlier, this was one of the major shortcomings of the CBA framework) and facilitate the diffusion of cleaner production practices and technologies, especially to developing countries.[11]

The second pillar concerns carbon leakage prevention. Climate change is a global problem. The majority of carbon reduction initiatives, however, are regional and unilateral. As an illustration, the number of implemented carbon pricing initiatives (ETSs and carbon taxes) at the national, subnational, or regional levels climbed to 73, according to the recent report of World Bank [2023]. In just 10 years, the share of global GHG emissions covered by these regional instruments increased from 7% to roughly 23%. In a similar vein, from the target-setting viewpoint, the majority of countries set their climate targets through their Nationally Determined Contributions (NDCs) under the Paris Agreement, which is once again determined at the national level. Therefore, as discussed previously, due to the lack of an international agreement that is legally binding, geographically limited and unilateral policies cause the problem of carbon leakage, which reduces welfare through decreased output and job loss channels in the region where the policies are being implemented and leads to an environmental policy ineffectiveness.[12] In this regard, border carbon adjustment, which implements the introduction of carbon price for imported goods to ensure that imported goods are subject to a similar climate-related cost as goods produced domestically, is considered to be the key policy to address this carbon leakage issue. CBA, as in the case of border carbon adjustment, also extends this regional perspective of PBA to a global context and brings attention to the emission transfer issue that hinders global mitigation efforts by providing information to incorporate emissions embodied in international trade. Thus, CBA broadens the focus and enhances the effectiveness of climate mitigation policy while also contributing to coping with the carbon leakage issue [Cosbey et al., 2019; Steininger et al., 2014; Antoci et al., 2021; Naegele, Zaklan, 2019; Chen, 2009]. It should also be noted that the use of CBA would not be considered as contradictive by other countries, contrary to the border carbon adjustment, which is often interpreted as a protectionist measure undermining free trade. The use of CBA promotes dialogue between producers and consumers and integrates the discussion on emissions embodied in trade into a cooperative agenda.

The third pillar concerns the scope of regulated emissions. The internationally recognized GHG reporting protocol specifies three different emission scopes [World Resource Institute, World Business Council for Sustainable Development, 2004]. Scope 1 covers direct GHG emissions from sources under the company's ownership or control, whereas Scopes 2 and 3 are more concerned with indirect emissions, for example, the former covers the GHG emissions caused by the company's use of purchased electricity, heat, and cooling, and the latter includes any additional indirect emissions that occur along the value chain, including both upstream and downstream activities. Nevertheless, when calculating GHG inventories, only the company's direct emissions and some indirect emissions related to the purchased electricity are taken into account, which means that despite the importance of treating emissions embodied in trade, there is no consistent practice of taking a certain amount of Scopes 2 and 3 emissions into account [Makarov, Alataş, 2023; Ozawa-Meida et al., 2013; Hertwich, Wood, 2018]. This is a major shortcoming because, in some industries, these emissions account for a sizable part of all supply chain emissions. For instance, in the case of the publishing industry, scope 1 and 2 emissions represent only 6% of overall emissions in Australia and slightly more than 13% in the U.S. [Huang et al., 2009; Barrett et al., 2013]. In this respect, the inclusion of Scope 3 emissions in GHG accounting is critical and highlights the need for a consumption-based approach for emission calculation. This is because, as discussed earlier, compared to PBA, the CBA framework looks at emissions from a broader perspective and considers emissions associated with supply chains as well. From this viewpoint, one prominent argument in favour of CBA is the opportunity for the global climate change regime to cover more emissions. Therefore, it is crucial to

[10] Refer to T. Domingos et al. [2016] and Kander et al. [2015] for additional details and discussions.

[11] A recent study [Meng et al., 2023] empirically tested the role of technological adjustments in CBE calculation for carbon leakage and found that convergence in emission intensities (carbon emissions per GDP) and changing trade patterns between the Global North and South may lead to a decline in net emissions embodied in trade.

[12] If all markets were perfectly competitive and all externalities were eliminated, the effect of policy instruments on PBE or CBE would be the same. Yet, as this assumption does not hold, the effects of policy instruments at national level are not equal, meaning that the burden of two polices using either a consumption or production base does not lead to same emission reduction at the same cost [Steininger et al., 2014].

regularly calculate and disclose CBE along with PBE and gradually incorporate them into the process of setting emissions reduction targets.

The fourth pillar concerns just and efficient carbon regulation. Carbon pricing is a critical part of a strategy for efficiently reducing emissions and has been implemented using a variety of instruments, particularly in high-income countries in North America and Europe since the 2000s [World Bank, 2023; World Bank, 2017]. This supply-side policy design is the most efficient way to address the environmental effects of industrial production. However, it ignores the effect of other economic actors on climate change, such as households, who are the final consumers of this production and the main driving force behind this industrial output. Therefore, this institutional setting and viewpoint is accompanied by some concerns about justice, and it is argued that consumers should also bear some of the responsibility for any emissions caused during the production of the goods.[13] However, even if some studies clearly demonstrate the need for consumer-related factors to be taken into account, demand-side climate policies are rarely used. In this regard, the CBA approach may also help address these issues of climate justice and some previously ignored aspects of climate change mitigation by increasing the number of climate policy instruments, such as demand-side policy tools aimed at regulating individual consumption patterns, lifestyles, housing, infrastructure, and so on. [Lenzen et al., 2007; Creutzig et al., 2018; Creutzig et al., 2022]. In addition to this, the CBA approach can also offer a greater potential to combine climate change mitigation efforts with tackling other development problems, like inequality. For instance, [Chancel, 2022] demonstrated that 48% of global emissions can be attributed to the richest 10%. The CBA-based policy can be applied in this way as well to ensure that the rich and the poor bear an equitable share of the burden of combating climate change [Grigoryev et al., 2020] .

Demand-side policy instruments may include “nudging” households to choose goods with lower carbon footprints through carbon labels, advertising, and construction of social norms [Brunner et al., 2018, Castro-Santa et al., 2023; Panzone et al., 2024]. These practices are sometimes used now, but tracking country-level consumption-based emissions would give a new impetus for nudging measures from policymakers and would help to better link individual efforts of consumers and their voluntary measures to adjust their lifestyles with national climate targets.

Conclusion and Discussion: Role of BRICS

This article provides an overview of consumption-based emissions accounting and argues that its incorporation along with production-based emissions accounting provides a more comprehensive view of a country’s contributions to climate change and informs more holistic policy approaches.

Regular calculation and disclosure of consumption-based emissions (along with production-based ones) and their gradual integration into the process of emissions reduction target-setting would provide a new perspective on sharing responsibility for emissions, efficiently confront the problem of carbon leakage and reveal the necessity for dialogue and coordination between major producers and consumers of carbon-intensive goods, expand significantly the scope of emissions under regulation, and give countries an opportunity to use the wider range of decarbonization tools. The latter would include those that involve populations in mitigation efforts and also better link the price for carbon with the level of household consumption, which is important for coping with carbon inequality and promoting climate justice.

Consumption-based emissions accounting is slowly becoming a part of the mainstream in academic literature but is nearly ignored in the practice of carbon regulation. Some significant exceptions, however, exist. For instance, the UK statistical office provides detailed official measures of consumption-based emissions along with production-based ones.[14] India’s Prime Minister Narendra Modi declared an ambitious LiFE (Lifestyle for Environment) initiative that addresses the environmental effects of consumer behaviour patterns.[15] However, scaling up such initiatives and their integration into mainstream set of climate policies globally is still the matter of the future.

The PBA to emissions accounting has existed for more than three decades; institutional inertia makes it difficult to introduce any significant adjustments to it. One important problem is that importers of emissions embodied in trade are numerous while large exporters include only a small number of large emerging economies. For instance, total net emissions exports of five BRICS countries are nearly equal to total net emissions imports

[13] As sellers or other intermediate producers also benefit from this trade and choose to engage in the production of emissions, this statement does not dismiss or underestimate their responsibilities.

[14] For further information, please visit the following website: https://www.ons.gov.uk/economy/environmentalaccounts/articles/netzeroandthedifferentofficialmeasuresoftheuksgreenhousegasemissions/2019-07-24

[15] For further information, please visit the following website: https://www.niti.gov.in/life

of 38 OECD countries. Historically, OECD countries played a much more important role in building the international climate change regime, and there was no pressure from them to introduce CBE into the equation of coping with climate change. The major beneficiaries of CBA are BRICS countries. Of them, China, Russia, India, and South Africa[16] are the four largest exporters of emissions embodied in trade. The size of their economies and the volumes and dynamics of their emissions make BRICS countries crucial in coping with climate change. These countries also have a well-developed platform for a dialogue: a full-scale intergovernmental forum that covers both ministerial meetings and high-level political dialogue.

Naturally, BRICS may be a platform for the introduction of consumption-based emissions accounting to the edge of the political agenda. At the first stage, BRICS countries may agree on the calculation of consumption-based emissions on a regular basis, based on a single methodology recognized by all of them. At the second stage, targets for consumption-based emissions reduction may be set for the future on a non-binding basis, in addition to production-based emissions reduction targets set within NDCs. At the third stage, after CBE accounting becomes a part of the target-setting process, more active dialogue may be held on the policy instruments to reduce CBE along with the involvement of BRICS+ countries and other representatives of the Global South. After that, in a bottom-up manner, discussion of consumption-based emissions may penetrate the UN climate negotiations process. Constant progress in data and metrics, rising attention to carbon inequality, increasing carbon leakage, and failure of conventional approaches to emissions reduction will eventually place consumption-based emissions at the centre of the political agenda. However, the earlier it happens, the better. Coping with climate change requires not only global, but also comprehensive, solutions based on the understanding of the comprehensive nature of emissions and their linkages with uneven economic development across countries, international trade, and value chains. Considering consumption-based emissions is an important part of such solutions, and humanity has too little time for prevention catastrophic climate change to ignore it.

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[16] If emissions embodied in trade could be calculated including those related to land use, land use change, and forestry, Brazil is likely to be among the leaders, too.

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