Advanced Review

# Consumption-based carbon accounting: does it have a future?

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Internationally, allocation of responsibility for reducing greenhouse gas emissions is currently based on the production-based (PB) accounting method, which measures emissions generated in the place where goods and services are produced. However, the growth of emissions embodied in trade has raised the question whether we should switch to, or amalgamate PB accounting, with other accounting approaches. Consumption-based (CB) accounting has so far emerged as the most prominent alternative. This approach accounts for emissions at the point of consumption, attributing all the emissions that occurred in the course of production and distribution to the final consumers of goods and services. This review has a fourfold objective. First, it provides an account of the logic behind attributing responsibility for emissions on the basis of consumption instead of production. Issues of equity and justice, increased emissions coverage, encouragement of cleaner production practices, and political benefits are considered. Second, it discusses the counterarguments, focusing in particular on issues of technical complexity, mitigation effectiveness, and political acceptability. Third, it presents the spectrum of implementation possibilities—ranging from the status quo to more transformative options—and considers the implications for international climate policy that would accrue under various scenarios of adopting CB accounting in practice. Fourth, it looks at how CB accounting may be adjusted to fit with current political realities and it identifies policy mechanisms that could potentially be utilized to directly or indirectly address CB emissions. Such an approach could unlock new opportunities for climate policy innovation and for climate mitigation. 

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## INTRODUCTION

For nearly two decades, the international community has been struggling to find a strategy to allocate responsibility for reducing greenhouse gas (GHG) emissions. Equity and justice concerns have been of paramount significance in international negotiations on climate change ever since the adoption of the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Underwriting the UNFCCC is the principle of common but differentiated responsibility (CBDR), which acknowledges that countries have contributed by varying scales to the mounting problem of climate change, will be exposed to different levels of impacts, and have different capabilities (e.g., financial and technological) to mitigate emissions. Under the 1997 Kyoto Protocol, developed countries agreed to take on legally binding emissions reduction targets for 2012, recognizing

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their dominant role as historic polluters. However, as emission targets by developed countries alone would evidently be insufficient to address climate change, the 2011 Durban Platform recast equity and differentiation in the climate regime by calling for a roadmap toward an agreement that would include mitigation commitments for all major emitters irrespective of country classifications.[1] The debate thus progressively shifted from whether developing countries should participate in mitigation efforts to what type of mitigation contributions they should actually undertake. Absolute, intensity or deviation from business-as-usual targets featured, among others, as potential options during the deliberations of the 2014 Lima climate conference.[2] During the 2015 Paris climate conference, this 'firewall' between developed and developing countries was largely removed, and the Paris agreement historically calls for climate action to be undertaken by all countries, albeit with common but differentiated responsibilities.[3]

When the international community discusses mitigation targets, it is exclusively referring to emissions generated at the point of production, that is, emissions physically produced mainly through the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation within the jurisdiction of a given state. While production-based (PB) accounting is currently the UNFCCC's adopted accounting principle, concerns about its limitations in addressing emissions embodied in international trade have led to increased calls for a switch to, or an amalgamation with, other accounting approaches.[4,5] Consumption-based (CB) accounting has so far emerged as the most prominent alternative, as evidenced by the wealth of scholarly attention it has attracted since the turn of the century.[6,7] The CB accounting approach accounts for emissions at the point of consumption, meaning that it is the end consumer, instead of the producer, of goods and services who is allocated these associated emissions. The main difference, therefore, between the PB and CB accounting approaches is that application of the latter would entail a state with an abatement policy to cede responsibility for emissions associated with its export production and accept responsibility for the 'embodied' or 'virtual' emissions of its imported goods and services.[6] To address these attributed emissions, net importers could strengthen emissions reductions within their territories, reduce the consumption levels of their residents, or contribute to mitigation efforts in foreign countries.

Switching from a PB to a CB accounting system would have important implications for global mitigation policies and consumption patterns, given that 20–25% of overall carbon dioxide emissions are from the production of internationally traded products.[8–11] In this respect, several studies have highlighted the instrumental role of China in net emission transfers, especially so given the high carbon intensity of its energy system, which accounts for about 25% of its net carbon-trade balance.[12] Fischer[13] further notes that 55% of the growth in global carbon dioxide emissions during the 1990 to 2008 period were due to China, with exports accounting for one-third of this contribution. The Chinese example is characteristic of regional trends, whereby developed countries tend to be net importers and developing countries net exporters of emissions.[8,9,11,14] This is of course a tendency, and there are notable outliers—particularly Russia and former Soviet states in Eastern Europe.[8] Australia and Canada are also listed in the literature as net exporters of emissions,[8,11] even though their net emissions exports are small and these countries may therefore shift from one group to another. A more recent study by Arto *et al.*,[15] for example, lists them both as net emission importers. Country size (GDP, population, and area), as well as reliance on resources (domestic or imported) and manufacturing for exports are all factors influencing whether a country will ultimately emerge as a net importer or exporter of emissions.[8,11,16]

Existing research on CB accounting has focused more on technical aspects by developing and streamlining methods for calculating emissions embodied in trade, or using it to inform discussions on burden sharing and to distribute a global carbon budget amongst countries. A smaller but growing body of literature has taken a more political perspective on CB accounting, advocating or opposing its adoption as the UNFCCC's accounting principle. While several studies have argued that the adoption of a CB accounting approach would carry benefits for international climate change policy,[6] others have taken a more skeptical stance, doubting its effectiveness and political feasibility, as well as its overall applicability in a real-world setting due to methodological complexities.[17–19] This study aims to review this debate and outline the reasons why CB accounting has gained stature in international discussions on climate mitigation on the one hand, but has struggled to secure adequate political support on the other. We show that due to a range of technological and policy-related uncertainties, the CB accounting approach is unlikely to replace its established PB counterpart, at least in the foreseeable future. That said, the CB accounting approach represents an invaluable tool for the international community to better understand the effect of consumption patterns on emissions and take the response measures necessary to address emissions embodied in trade.

*The Case for CB Accounting* and *The Case against CB Accounting* sections discuss the variation in opinions in the literature by outlining the opportunities that would arguably arise from adopting CB accounting, as well as the problematic aspects that could potentially emerge. *The Spectrum of Implementation Possibilities* and *Implementation Policies* sections then present the spectrum of implementation possibilities, ranging from the status quo to more transformational options, and identify policy mechanisms that can be utilized to directly or indirectly address CB emissions. Some of these policies are more controversial than others and it would be overly optimistic to expect that such an approach would resolve many of the challenges of climate governance. It could, however, offer an important new perspective and help to inform on-going international climate change negotiations.

## THE CASE FOR CB ACCOUNTING

The CB accounting literature has highlighted a number of benefits that could accrue from attributing responsibility for GHG emissions on the basis of consumption instead of production, mostly on the grounds of increased emissions coverage, encouragement of cleaner production practices, political acceptability, and equity and justice. Taken together, proponents of such an approach argue that its adoption could enable the international community to move closer toward achieving the ultimate objective of the UNFCCC of avoiding dangerous anthropogenic climate change.[20]

### Emissions Coverage

One of the most prominent arguments in favor of CB accounting is the opportunity for the global climate change regime to cover more emissions. First, this is mainly the outcome of bringing the export sectors of developing countries, which are generally more carbon-intensive compared to those of their developed country counterparts, into the scope of international climate policy. From the perspective of the Kyoto Protocol, this advantage was strongly highlighted, given that more emissions would be covered without necessarily broadening participation beyond developed countries. Following the adoption of the Paris agreement, this argument is somewhat outdated, as virtually all countries have issued pledges and all emissions are now covered. That said, CB accounting would still offer an opportunity to the international community to better understand the impact of trade on global emissions and thus address the challenge whereby developed countries clean up domestic production by merely shifting it elsewhere.[11]

Second, the UNFCCC's PB accounting approach does not cover GHG emissions arising from aviation and bunker fuels. Currently, such emissions are not allocated to individual countries, being only reported as a memo item to their national GHG inventories.[10] This situation arose due to uncertainties about allocating responsibility. Harris and Symons[21] note that allocating them on the basis of cargo/passenger destination was considered prior to the adoption of the Kyoto Protocol, but lack of adequate data resulted in such proposals being dismissed as impractical. Recent efforts by the European Union (EU) to incorporate international aviation emissions into its Emissions Trading Scheme (ETS) have been met with resistance from, *inter alia*, major developing countries, who questioned the proposal's consistency with the cornerstone UNFCCC principle of CBDR. Adopting a CB accounting approach could resolve this impasse, as consuming countries would assume responsibility for emissions associated with the international transport of goods.

Third, a further practical advantage stemming from the application of the CB accounting approach is arguably the opportunity for the climate change regime to cover emissions embodied in trade and thus deal with strong and weak 'carbon leakage.' Strong carbon leakage, also known as policy-induced leakage, occurs when carbon-intensive sectors of an economy decide to relocate their manufacturing base from a developed country which may have introduced carbon price legislation, like for example an emissions trading scheme, to a developing country that is currently subject to limited emissions controls.[22,23] Such 'off-shoring' of emissions may result in relative decarbonization in wealthy nations, but such effects are nominal at best as emissions reductions are more than counterbalanced by the importation of cheaper, yet often more carbon-intensive, substitutes from what can be less regulated locales of the global economy.[24] Aichele and Felbermayr[25,26] found strong evidence for carbon leakage in various industries, such as basic metals or paper and pulp. However, the occurrence of strong leakage is contested[27–29] and more empirical data are required before safe conclusions can be drawn. Currently, the literature suggests that the drivers of traded carbon are too diverse to be solely attributed to off-shoring due to stringent environmental standards or cleaner production patterns in developed countries.[11,17,30]

Weak carbon leakage, however, is unrelated to mitigation policy within developed countries, being instead the result of two issues. First, the desire of companies in developed countries to reduce employment and regulatory compliance costs by relocating to the global South.[7] Second, the import of goods manufactured by native companies in foreign countries with higher competitive advantages and lower costs. Peters[22] has provided strong evidence for the latter cause and considers weak carbon leakage to be driven by demand. He thus defines weak leakage as the amount of emissions that are generated outside a given country in order to meet its local consumption requirements. Weak leakage constitutes an important matter, as clearly reflected by the significant rise in net emissions transfers. Various studies show that GHG emissions embodied in imports of goods and services intended to satisfy domestic consumption are progressively overtaking those embedded in domestic production, a trend likely to persist under current international policies.[8,9,31] Davis and Caldeira[8] note that 23% of global carbon dioxide emissions in 2004 were traded internationally, primarily as exports from China and other emerging markets to consumers in developed countries. Using the United Kingdom (UK) as a case study, Barrett *et al.*[10] note that an equivalent volume of GHG emissions associated with goods and services to satisfy UK consumption were emitted outside the UK as those emitted inside its borders. They further highlight that the increase in UK emissions transfers is from countries not covered in Annex B of the Kyoto Protocol, mainly in Asia. Druckman *et al.*[32] reach similar conclusions, showing that any achievements on the part of the UK in reducing its PB emissions are negated when a consumption perspective is adopted.

Such net emission transfers have been growing at an average yearly rate of 17%, exceeding the reductions in production emissions that developed countries as a whole have achieved in the same period.[9,13] In other words, developed countries have increased their CB emissions faster than reducing their PB emissions; or, as Rothman[33] notes, consumers in wealthy nations have simply passed 'the buck to people in other places or in other times.' Hence, while many developed countries may have met their actual Kyoto Protocol commitments, the associated increase in the emissions of developing countries that are producing their imported goods and services cancels out, and even outstrips, their domestic mitigation inroads.[14] Adopting a CB accounting approach, therefore, would cover more emissions and help tackle this phenomenon.

## Encouragement of Cleaner Production

A shift toward CB accounting practically entails bringing the export sector of developing countries into the scope of international climate policy; a move that CB accounting proponents argue has clear benefits in terms of facilitating the diffusion of cleaner production practices and technologies to these countries. As Barrett *et al.*[10] explain, energy production, energy-intensive sectors and transportation are the main sources of emissions coming under the spotlight of PB accounting, whereas a CB accounting approach would bring to the forefront the contribution of services, plus that of manufactured products like electrical appliances, food, and textiles. With the services sector becoming an ever increasingly important component of their economies, developed countries turn into substantial procurers rather than producers of manufactured goods.[34] Following an international division of labor, developing countries have assumed a more prominent position in the production and international trade of manufactured goods. Yet, a series of studies has highlighted that the carbon content of developing country exports is much greater than that of their developed country counterparts.[8,9]

Emission inventories based on consumption, rather than production, imply the need for policy instruments capable of tackling the emissions of such key traded products. As a consequence of adopting CB accounting, therefore, developing countries would be encouraged to implement energy efficiency improvement strategies and reduce the carbon footprint of their export production in order to safeguard their access to foreign markets. They could even, as Peters and Hertwich[24] observe, use improved environmental performance as a marketing tool against competitors targeting similar export markets. However, as will be highlighted later on, this would require support in the form of technology and/or finance to give developing countries the capacity to compete fairly in the world market.

To undertake successful domestic action by engaging with CB accounting-related policies that would entail developing countries reducing their emissions or, at least, regulating them, would require close cooperation with importing partners. As a result, CB accounting could support the case for targeted technology transfer initiatives between trading partners.[20] For instance, the Kyoto Protocol's Clean Development Mechanism (CDM) concept is totally compatible with a CB approach, given it was designed from the outset with the intention of developed countries assuming more responsibility than that defined by their territorial emissions.[11,31] The prospects for streamlining the CDM have thus been pinpointed, with Peters[5] positing that a CB accounting approach would allow project sponsors to enact mitigation projects in areas that reduce consumption emissions in importing countries. Of course, because a CDM action in a developing country would reduce the CB emissions of several of its trading partners, the resulting CDM reductions would need to be counted toward meeting the mitigation targets of the sponsoring countries alone.

In addition to enhancing green technology transfers, the provision of incentives for investing in cleaner and more efficient production systems in developing countries has the advantage of presenting the international community with further, more cost-effective mitigation options, particularly given that in excess of two-thirds of the lowest-cost abatement opportunities currently lie in developing countries.[21] Developed economies are relatively clean, thereby facing high marginal costs for reducing emissions. Toughening territorial emissions targets further, in the absence of developing country participation and without the enactment of CB measures, would not only be costly, but could potentially also encourage leakage.[35]

## Political Benefits

Prior to the 2015 Paris Agreement, the literature highlighted the potential of the CB accounting approach to encourage global participation in mitigation efforts and stimulate the crafting of a new multilateral climate change agreement.[36] Mitigation commitments under the Kyoto Protocol were negotiated during the mid-1990's, with Parties being split into two main groups: Annex I and non-Annex I. The former had binding quantitative commitments and reporting obligations, while the latter had qualitative obligations, more lenient reporting requirements and eligibility for financial and technological assistance.[37] The expectation had been though that as emissions in major non-Annex I Parties grew they would gradually take on obligations similar in nature to those of their Annex I counterparts. However, major emerging economies largely continued to evoke the CBDR principle to avoid assuming responsibilities on par with developed countries.

Detrimental to the success of the Kyoto Protocol was the refusal of the United States (US) in 2001 to ratify the Protocol on the basis that it excluded high emitting developing nations and it would harm the US economy. Canada, Japan, New Zealand, and Russia have since withdrawn from the second commitment of the Kyoto Protocol, citing similar concerns. It had therefore been argued that switching to CB accounting could have provided the incentives necessary for these developed countries to re-engage with the Kyoto process, as well as introduce emerging economies into a global climate agreement. In contrast to PB accounting and the Kyoto Protocol's notion of differentiated responsibility, adoption of the CB accounting approach would alleviate to a great extent the competitiveness concerns of several developed countries that have so far refrained from signing up to binding emissions targets in the absence of some degree of equivalent commitments by major developing country emitters. Indeed, as Girod *et al.*[38] note, domestic industries in developed countries could be disproportionately disadvantaged in both home and foreign markets by policies explicitly targeting production-side variables, like for instance unilateral environmental taxes. In an era of globally integrated goods and capital markets, differentiated responsibility equates to differentiated costs depending on an emitter's geographical location. In addition, the environmental effectiveness of such measures is also curtailed by the fact that in most cases producers of energy-intensive goods, like for example steel or cement, are exempted due to competitiveness concerns.[38]

The CB accounting approach addresses competitiveness concerns because the cost of exported products is not affected, and also because both imported and domestically produced products in a home market are required to comply with the same environmental legislation, that is, a carbon tax or a mitigation commitment.[24,38] An international climate change regime that is grounded in a properly crafted CB accounting mechanism could therefore strengthen the case for promulgating policy measures aimed at reducing embodied emissions in developed world consumption, hence helping create in the process a broader coalition with a shared political vision toward more global actions.[21]

The above arguments continue to apply to a great extent even after the adoption of the 2015 Paris Agreement. Parties submitted voluntary (i.e., nonbinding) targets that even if implemented in full will be grossly inadequate in keeping global warming below 2°C.[39] This approach of adopting an insufficient and nonbinding agreement was apparently the only one acceptable to all Parties.[40] The agreement largely ends the dichotomy between developed and developing countries, but a degree of differentiation is still present. While the agreement notes the principle of differentiated responsibilities and respective capabilities, it adds 'in the light of different national circumstances,' thus allowing for a more dynamic interpretation.[40] As is noted in the agreement, industrialized countries are to undertake absolute GHG reductions, while developing countries are to move to economy-wide targets over time. Such differentiation could have short- or medium-term implications for competitiveness. That said, the request on Parties to 'communicate or update' these pledges on a five-yearly basis is an important one in that it signals a shared understanding among them that each successive review should lead to further strengthening of target ambition. This conclusion is further collaborated by the surprising inclusion of the aspirational objective to cap temperature rises at 1.5°C above preindustrial levels. The Paris agreement did reinvigorate the climate regime; yet it will require serious political commitment to deliver.

### Equity and Justice

Starting with equity and justice, a number of studies have argued that pressure on environmental ecosystems is a direct consequence of affluence and unsustainable consumption practices in developed or affluent countries.[41–43] Subsequently, as increased consumer demand is ultimately driving production patterns, some argue that responsibility for any emissions caused in the process should fall on the final consumers themselves.[5,6,23] Others take a contrasting stance, arguing that producers should also have a share of responsibility because it is them that decided in the first place to engage in the production of goods and services and to promote consumer demand for these products in order to harvest the associated economic and home-country employment benefits.[44]

Another argument relating to equity and justice revolves around the issue of historical responsibility. Raupach *et al.*[41] and Wei *et al.*[43] estimated that developing economies have contributed only 23% of global cumulative emissions and are responsible for only about 20–40% of the global average temperature rise since the preindustrial era. This estimate not only stresses the ecological debt held by industrialized states, but also the rights of developing countries to improve the living standards of their populations without carrying an excessive mitigation burden. Based on this optic, Ferng[45] proposes that those states that hold an ecological deficit (i.e., debt) should bear the obligation to assume a larger share of the overall mitigation costs. Baer *et al.*[46] and Kartha *et al.*,[47] in turn, have developed the Greenhouse Development Rights Framework, according to which states with an average income per capita below a threshold of approximately $16 to $20 US dollars per day should be exempt from bearing mitigation costs. This idea relates directly to the capability or 'ability to pay' principle, according to which developed countries should shoulder a greater quota of mitigation cost burdens due to their greater levels of wealth and capacity to act.[48] Developed countries, in contrast to their developing country counterparts, are therefore thought of as being better positioned to implement emission reduction obligations without disproportionately compromising welfare delivery.[23] As impacts from consumption are shifted from one location to another, adopting a PB accounting approach implies that developed countries do not in reality face up to their historical responsibility for the build-up of GHGs. If a production perspective is taken, developed countries may give the impression that they are succeeding in reducing their emissions, which is not accurate if viewed from a CB perspective. However, a CB approach would free a larger portion of the carbon budget to the developing world. Following this line of thinking, Peters *et al.*[9] also argue that while the PB accounting approach may currently benefit economic growth in developing countries, the latter will find themselves worse off in the future, as efforts at curtailing their increased emissions will by then be more costly, especially for those that will have assumed their own emission reduction targets.

## THE CASE AGAINST CB ACCOUNTING

While several studies have highlighted to policymakers the advantages of applying a CB accounting approach, various others have adopted a more skeptical stance, bringing to the fore a wide range of complications that would interfere with or prevent initiation of implementing policies. These could be grouped into three main categories: effectiveness/efficiency concerns, practical impediments, and political incompatibility.

### Effectiveness and Efficiency Concerns

Critics of the CB accounting approach have questioned it on grounds of effectiveness and efficiency. First, Liu[17] argues that both the CB and PB accounting approaches ultimately share the same goal, namely to use policies, so as to urge producers to reduce emissions. The former intends to achieve this goal indirectly by impelling consumers to exert pressure on producers, while the latter aims at producers directly. He then goes on to argue that while current environmental regulations and policies target producers, inserting consumers into the equation would result in intricate policymaking procedures with diminished practicality. Consequently, he concludes, it would make better sense to induce producers to invest in cleaner production practices and then simply pass extra costs to the consumers.

A second criticism comes from Jakob *et al.*[18] who argue that advocates of CB accounting normally do not take into account the general equilibrium implications that determine the global patterns of production and consumption. Jakob and Maschinski[12] and Jakob *et al.*[49] refer to trade theory to demonstrate how regulating climate change based on consumption emissions does not guarantee a greater reduction in global emissions compared to PB accounting, and could even result in an increase in global emissions. Pricing emissions embodied in imported goods does not avoid the same quantity of emissions. They show how the regulation of emissions embodied in EU imports of Chinese goods would result in an increase of carbon leakage by shifting Chinese production from its export markets to more carbon intensive nonexport sectors. Whilst CB accounting promotes the reduction of net imported emissions, what ultimately matters is the difference in the carbon intensity of foreign export markets compared to their domestic markets as trade distortions are likely to shift foreign production from export to domestic sectors, which are often more carbon intensive. In this sense, Jakob *et al.*[18] argue that CB accounting does not necessarily provide a direct link between a country's actions and changes in emissions. For instance, they provide a hypothetical scenario whereby the EU could employ its dirtiest technologies to produce exports without affecting its emissions account.[18] Along similar lines, the same authors mention that if less regulated countries, like China and India, were to cease trade and meet all their consumer demands domestically, emissions would not significantly change as higher carbon intensive domestic production would be offset by lower carbon intensive domestic production in regulating countries. Essentially, it is not proven that the accounting approach would increase the effectiveness and efficiency of climate mitigation.

Third, researchers highlight *inter alia* the need to factor in rebound effects, where energy efficiency improvements will increase rather than reduce energy consumption.[50] While this is obviously independent of accounting approaches, the fact remains that a CB one may well stimulate investments in emission reductions and energy efficiency. However, these will not pave the way for a decoupling of economic growth and environmental deterioration unless rapid consumption growth is urgently addressed. As Liu[17] notes, a drop in emissions by 50% due to cleaner technologies would be negated by a doubling of production/consumption. As Isenhour and Feng (Ref 51, p. 7) argue, a valid point to be made is whether attempts by developed countries to address their consumption emissions through promoting the transfer of technologies into developing countries 'simply rationalizes accelerated consumption and a globalized rebound effect.' Consequently, as Barrett *et al.*[10] posit, it is imperative to consider rebound effects, so as to obtain a realistic assessment of the scale of possible emissions reduction.

## Practical Impediments

CB accounting reallocates emissions from the producing industrial sectors to the final consumers of products. Although the two accounting approaches represent the two sides of the same coin, their differences have widespread implications when it comes to compiling national emissions inventories. As already noted, a PB system would measure emissions physically produced within the jurisdiction of a given state, while a CB inventory would deduct emissions embodied in its exports and factor in emissions embodied in its imports. The PB accounting approach was deemed favorable by UNFCCC parties, given its simplicity relative to CB accounting, consistency with current methodologies for compiling energy statistics and suitability for 'differential reporting processes among different states' (Ref 18, p. 13). It is important to note that all accounting schemes suffer from a degree of uncertainty. When it comes to PB accounting, for instance, poor statistical infrastructures in many developing countries are a constraining factor when it comes to producing accurate emissions inventories.[52] In addition, different global datasets generate different emissions inventories.[53] For example, Guan *et al.*[54] found that Chinese provincial carbon dioxide emissions calculated from energy usage exceed the national reported emissions account by 1.4 gigatonnes.

Yet, constructing CB national emissions inventories is an inherently more challenging process, as they are typically based on PB accounting while also employing additional modeling assumptions, like sectoral carbon intensities in international trade. Consequently, they 'suffer from both the statistical uncertainties of PB accounting and those stemming from their own assumptions' (e.g., uncertainties related to the assumptions embedded in the models used to determine them) (Ref 44, p. 4). To be properly constructed, they would require practically all traded goods to be registered with their carbon content.[55] Monitoring and measuring embedded carbon is a more complex methodological process, with data uncertainty (derived from data quality and availability of main trading partners and more complex calculations than in PB accounting) and inadequate reporting being referenced as stumbling blocks that could confound the entire process.[24] As production emissions are used in the calculation of consumption emissions, Peters *et al*.[56] found that the uncertainty involved in the compilation of PB inventories is greater than the uncertainty associated with the economic and trade input data used in CB accounting. As China is the world's largest exporter of goods, uncertainties around its production emissions[54] will affect the CB accounting of its importers. Problems can be further exacerbated by lack of capacity in the great majority of developing countries to develop such demanding CB inventories, especially at a time when the UNFCCC Secretariat provides on-the-ground assistance to developing countries in preparing their PB accounting-based national inventories.[21]

An additional impediment for a state aspiring to put in place an accurate and reliable CB inventory relates to the need for compiling data from its numerous trading partners. A multitude of traded products have various components, many of which are produced in a constellation of different countries. The greater the complexities of the international supply chain in question, the greater the nebulousness when it comes to data quality and availability.[24] Harris and Symons[21] refer to the automobile industry as an illustrative example. A PB accounting approach would allocate emissions from the manufacturing of the automobile's different components to the inventories of the different countries along the production chain. A CB accounting system, however, would allocate emissions from all manufactured components directly to the country importing and selling in its domestic market the final product, that is, the automobile.

Finally, the preferred method for constructing CB accounting inventories at national and supranational levels is multiregional input–output analysis (MRIOA).[20,57] An MRIO model gathers domestic and import input–output tables from a number of individual nations or regions, combining them to form a single aggregated matrix, reconciled by trade statistics. This matrix represents the supply chain, capturing the inter-industry relationships between all the trading partners. Such a model is useful not only for allocating emissions (or other environmental extensions) to final demand, but also for estimating the changes in production (or emissions) in one region derived from changes in final demand registered in others.[58] One of the major drawbacks of these models is that they require large amounts of data harmonized according to sector classification, base year prices and a unique currency. Data of this nature are often not readily available, requiring the modeler to introduce a number of assumptions to replace any missing values.[20] As can be noticed, the complicated calculation and formalization processes involved, as well as the data-intensive and assumption-prone nature of CB methodologies, severely limit the prospects of CB accounting being promulgated via an international agreement in the near-to-medium term.[17,55]

## Political Incompatibility

Ideally, at least from an economic perspective, an international climate change regime operating under the CB accounting approach would be mostly effective if a global tax on GHG emissions were to be introduced, as the price of the product would reflect the impact.[59] As noted earlier, for such a scheme to function properly, you would first need accurate information on carbon embodied in every produced good, so as to put in place an adequate taxation system. Following that, you would need all the revenue collected via these carbon taxes on the exports of developing countries to be disbursed back to them so that they can be subsequently invested in 'greening' their export production. Such a transformative scheme, however, could only be put into place by means of an international treaty, that is, via almost universal cooperation. Consequently, critics argue, such policy designs border the realm of impossibility, at least in the short-to-medium term.[19]

Even if we were to assume that a CB accounting-based regime were to be actually considered by the international community, another obvious complication would arise from the fact that under a CB accounting inventory system a country is attributed with emissions that were emitted outside its area of jurisdiction, that is, in a different country or countries. Whether developed countries will accept liability for emissions they have no control over is a key question.[13] A similar argument also applies to developing countries; would they be prepared to allow developed countries to exert influence over PB activities taking place within their borders? Assuming they do, the level of collaboration required to design and put in place CB inventories would go way beyond what the international community has been accustomed to in current UNFCCC deliberations.[5] An issue that will surely emerge will concern the manner in which the embodied emissions of developing country exports are monitored, reported, and verified (MRV) by the international community to provide transparency and ensure compliance of the developed countries that have taken over responsibility for mitigating them.

In the aftermath of the 2009 Copenhagen climate conference, developing countries rejected MRV for policies that were unsupported internationally, citing infringement of sovereignty as a justification.[60] However, under a CB accounting system such a stance cannot be maintained. If the US government were to be assigned responsibility for part of China's emissions, you can expect the former to demand that the international community, via for example the UNFCCC, has direct control over China's MRV promulgating procedures. MRV is vital for progress on emissions reduction and lack of transparency could delay progress, or stop it altogether. A danger, therefore, with adopting a CB accounting approach is that resolving MRV-related complications could result in prolonged and time-consuming international negotiations.

## THE SPECTRUM OF IMPLEMENTATION POSSIBILITIES

The preceding sections have outlined the arguments for, and against, the adoption of CB accounting. Given this debate, the question is raised as to the potential options facing the international community. In other words, can CB accounting play a role and if yes, how? There are three main options according to the literature that merit further investigation, from one end of the spectrum to the other. The first and second are rather transformative in nature and entail the international community formally adopting CB accounting and engaging in remedial action aimed at tackling the limitations outlined above. The third one is simply continuing with the status quo, in which CB accounting is merely used on a voluntary basis.

The first option is *full replacement*, that is, the complete substitution of PB accounting for CB accounting as the accepted official foundation for accounting emissions. This option represents one extreme of the spectrum and implies that net-importing countries assume full responsibility for the emissions embodied in their imports, elevating their mitigation burden and making their legally binding targets significantly more stringent. The literature, however, has scarcely explored this option, with only a handful of studies having examined its potential implications. Steckel *et al.*,[59] for instance, argue that the initial allocation of emission allowances among countries (e.g., per capita basis, historical responsibility, etc.) would represent a contentious issue. Different allocation rules could favor either net-importing or net-exporting countries, engendering welfare distribution effects. However, the authors also show mathematically that if a global cap-and-trade regime with full emissions coverage was in place, both emission accounting principles would ultimately be equivalent in terms of efficiency of production and welfare distribution. The authors allege that in both approaches mitigation costs would be generally borne by consumers, either directly or indirectly. Peters and Hertwich (Ref 24, p. 58) have proposed the application of a harmonized global tax 'based on the carbon content of fossil fuels independent of the country.' Ghosh and Agarwal,[61] however, assert that under CB accounting marginal abatement costs (MACs) would be higher than under PB accounting, mainly due to limited substitution possibilities between energy and nonenergy goods in final consumption. In a similar vein, Jakob *et al.*[18] cast doubt on the effectiveness of this option, declaring that, in principle, CB accounting would not lead to a socially optimal outcome. According to them, the Pigouvian rule of introducing a price that is equal to the social costs of an externality cannot be applied to emissions embodied in imports. As has been mentioned, this is due to the fact that avoiding one unit of imported emissions (e.g., via a carbon tax or another instrument) may not be equivalent to preventing the release of one unit of emissions to the atmosphere. Furthermore, the authors warn that its actual implementation could be plagued with serious practical problems, such as obtaining up-to-date information on the carbon content of individual products and high operating costs.

The second option is to go for a middle ground approach and design a '*shared responsibility*' regime which splits the mitigation cost burden between producers and consumers at various degrees, depending on the extent to which different entities are willing to cooperate in abatement actions. Unlike the full replacement option, relatively more attention has been devoted in the literature to examining such 'limited-' or 'shared-' responsibility' schemes, with manifold frameworks having been advocated whereby responsibility is shared between producers and consumers, mostly from a theoretical perspective.[62,63] Such studies can be broadly classified according to two research strands. The first one analyzes how responsibility can be allocated in general terms or concentrate on a single country and its economic sectors. In this area, Gallego and Lenzen[64] and Lenzen *et al.*[65] conceptualize a more formal 'shared' framework, whereby responsibility is apportioned depending on the benefits obtained by each actor along the supply chain, from the producer through to the consumer. Andrew and Forgie[44] later applied this technique to examine the case of New Zealand. Their results show that producers would be responsible for 44% of domestic emissions, while the rest would be taken by national and foreign consumers. Cadarso *et al.*[66] did something similar for Spain, by suggesting shared responsibility depending on the value added at each step of the product chain. By applying their method, they found that Spain's share of responsibility as a producer country would be 34.4% higher than its PB emissions in 2005, but would be around 6% lower than its overall CB accounting emissions.

The second research strand involves examining how to apportion responsibility between different countries by taking into account international trade flows. Ferng,[45] for instance, suggests that responsibility should be allocated to both net-producing and net-consuming nations, because both obtain benefits from their respective activities. Their specific shares, however, would be subject to international negotiations, considering the differences in economic structures, as well as income and consumption levels in each of the participant states. Bastianoni *et al.*[67] suggest a particular method, which they call the 'carbon emission added' approach, which follows a similar logic to the concept of value added. Countries, in this sense, assume co-responsibility for the emissions that are 'added' at each stage of the global supply chain. Marques *et al.*,[68] in a similar line of reasoning, propose a downstream technique, as opposed to the CB accounting upstream approach, whereby nations become responsible for those emissions that are necessary to generate their income (i.e., payments to the factors of production: wages, profits and rents) via international trade. Following a different rationale, Chang[69] designed a shared framework from the perspective of border tax adjustments, in which the carbon tariff rates serve as weights to apportion emissions between participating economies. Kander *et al.*,[70] in turn, have proposed a technology-adjusted CB accounting approach whereby countries are credited for having greener exports than the world average, meaning their consumption account is reduced. Those countries exporting more carbon-intensive goods than the average on the global market are allocated a higher consumption account. Otherwise countries are not credited for cleaning up their exports and some types of carbon-beneficial trade are discouraged.

Implementing shared-responsibility schemes, however, would face some of the difficulties discussed earlier. In political terms, as has been noted by Ferng,[45] complex international negotiations would be required to establish the share of emissions that different states would be responsible for. Moreover, rules to ensure transparency and compliance would need to be agreed at an international scale, including any MRV issues usually raised by developing nations. In relation to practicality matters, the reporting of CB emissions would be subject to the technical complexity of constructing credible and robust CB emission inventories. Regarding effectiveness concerns, it is ambiguous if such a scheme would contribute to delivering deeper emissions cuts more rapidly compared to the status quo.

The third option, at the opposite end of the spectrum, is represented by the continuation of the *status quo*. In simple terms, this means preserving PB accounting as the formal emissions accounting approach while adopting CB accounting on a voluntary basis. A number of actors have demonstrated interest in such approach, like for instance the Organisation for Economic Co-operation and Development (OECD), which has undertaken a first effort to make public the CB emissions of its member countries and other developing nations.[71] The UK government serves as another pertinent example, as it makes public the country's CB emissions inventory.[72] Following this action, the UK parliamentary committee on energy and climate change was motivated to undertake an inquiry into CB accounting to examine its practical feasibility and potential repercussions for national carbon budgets.[73] In its conclusions, it urged the government to explore the potential for integrating CB accounting into national policy making processes, alongside PB accounting, so as to obtain a more complete understanding of the country's impact on the global climate and encourage the development of new policy options. This stance is significant, as this might influence other states to follow similar courses of action. Moreover, it might constitute a stepping-stone toward more ambitious levels of implementation in the future.

As has been said, CB accounting is currently used for voluntary reporting. Various analysts have posited that CB accounting has a great potential as a diagnostic tool that could enable national governments to acquire a better understanding of the impact of their consumption choices, and thus design policies and tools that can go some way toward mitigating the associated but currently unregulated emissions.[18,52] However, this could be strengthened by making reporting mandatory, thus enabling CB accounting to better inform mitigation actions that escape regulation and helping governments to avoid, whenever possible, any course of action that may lead to an additional rise in emissions outside their natural area of influence. Mandatory reporting in other words would enable the international community to harness the complete potential of this tool.

Such an approach not only has benefits at the international level, but also at a subnational level, for example for businesses and cities.[74] Whilst companies currently are not mandated to calculate their off-site supply chain emissions, monitoring them would provide them with a better understanding of the potential risk of resource and carbon price fluctuations on their business/service provision activities, both related to their upstream purchasing and loss in sales.[75] CB accounting could therefore raise awareness allowing organizations to realize efficiency improvements along their global value chains and to manage aspects of risk.

To conclude, a complete redesign of the international climate change regime in favor of CB accounting seems unlikely at this stage. Significant methodological, political and other uncertainties remain with respect to the potential benefits of adopting shared responsibility schemes or moving toward a full CB accounting regime. Yet, a limited number of international actors are currently exploring the potential of voluntary reporting of their consumption emissions in order to better understand the impact of their consumption choices on the global environment. While this trend should be of course encouraged, promulgating mandatory reporting would be a decisive step that would allow the international community to design effective policies and tools to mitigate emissions embodied in trade.

As the above analysis has highlighted, the current PB accounting approach is undoubtedly here to stay. Yet, traded emissions still merit the need to be addressed, as they undermine mitigation targets in regulated countries. The following section outlines a number of readily available policy options that could prove to be useful in dealing with CB emissions under the current PB accounting approach.

## IMPLEMENTATION POLICIES

Following the 2015 Paris agreement, the global consensus on climate change action has been revitalized. However, reducing emissions in line with a 2 degree, or lower (i.e., 1.5 degree), future is likely to require a reduction in absolute demand, at least while we wait for global scale decarbonization and negative emissions technologies to be deployed.[76,77] Consumption accounting identifies: (1) emissions intensive trade flows to ensure impacts from consumption are not shifted from one location to another and (2) high impact consumption activities where policy can intervene to reduce aggregate emissions. Domestic policies can therefore intervene to mitigate traded emissions directly via trade mechanisms, or indirectly by reducing emissions in countries outside one's territory, as well as implementing domestic actions focused on consumption.

What follows are examples of such policies—some more controversial than others—that could address consumption emissions under a status quo approach. These are not a definitive list of policy options, and not specific to CB accounting, but we have analyzed policies that are outside the mainstream, of which the current focus is overwhelmingly on the deployment of domestic cleaner production technologies. Even within the CB literature there is a bias toward border carbon adjustments, with much less attention toward policies focused on consumption patterns.

### Trade Mechanisms to Address Emissions Embodied in Trade

When resorting to unilateral measures, applying border trade adjustments for both imports and exports has been suggested as an alternative.[78–81] In general, these include three types of measures: border taxes (import tariffs or rebates on exports), mandatory emissions allowance purchases by importers; and embedded carbon product standards.[82] Such border carbon adjustments would essentially tax imports according to the emissions associated with their production, thereby ensuring a level playing field with domestic competitors who are subjected to firmer environmental policy and enforcement rules.[83] In addition to import charges, border rebates for exports would serve the same purpose for producers competing in foreign markets. In other words, the argument in favor of border carbon adjustments is that countries should not enjoy a competitive advantage because of their weaker climate polices.[84] Trade restrictions could thus be used in order to deter or punish free riding, via prohibiting or imposing higher taxes on the exports of countries whose nonparticipation compromises the environmental effectiveness of the climate change regime. As Barrett[85] notes, some of the most effective international environmental agreements to date, like the Montreal Protocol, actually incorporate various forms of trade restrictions.

Such an approach has been strongly advocated by some analysts and even policymakers, with former French President Nicolas Sarkozy tabling it in 2006, causing a heated discussion at the time in Europe and elsewhere.[86,87] Yet, a number of concerns have surfaced in the literature regarding its applicability in a real-world context, relating *inter alia* to the potential for increased carbon leakage, negative welfare impacts and incompatibilities with established trade norms.

### Border Trade Adjustments and Carbon Leakage

Jakob *et al.*[18] state that border carbon adjustments are not optimal policy tools to address emissions embodied in trade. They note that price changes will induce a change in the structure of production and consumption as alternative product sources are sought, which can both increase or reduce carbon leakage. As they explain, the avoidance of importing one unit of emissions does not necessarily translate to avoiding one unit of emissions into the atmosphere; it just changes where the emissions are emitted, which is largely dependent on the carbon intensity of production. To be effective, such tools will need to be complemented by measures reducing the absolute volume of GHGs generated. Despite evidence showing that industrialized countries have managed to stabilize their production emissions partially due to growing imports from developing countries, the use of materials, which embody emissions, is almost absent from climate policies.

Another argument relating to leakage is that carbon adjustments at the border could impact on the comparative advantage of developing country exports, especially those with a high price elasticity of demand, thus detrimentally affecting the country's in question balance of payments.[49,88,89] China, for example, the world's largest exporter of emissions, could suffer substantial losses, estimated to be as much as 4% of its GDP.[90] However, should that occur, tackling the resulting deficits could necessitate the scaling back of imports and their substitution with domestically produced, potentially more carbon-intensive alternatives.[17] Hence, reduced export revenues could result in what Jakob and Marschinski (Ref 12, p. 22) refer to as 'consumption leakage.'

### Border Trade Adjustments and Welfare Implications

Loss of developing country export revenues as a consequence of border trade adjustments would fare negatively in terms of social justice and equity due to the potential negative welfare effects on exporting developing countries as a result of consumption leakage.[6] Such measures could even risk being negatively associated with 'green protectionism' or 'eco-imperialism.'[55] To overcome these CB accounting-related complications and maintain stable levels of trade growth, developing countries would need to reduce the embodied emissions of their traded products on the one hand, while maintaining and even enhancing their comparative advantage on the other. To satisfy such prerequisites, developed countries would have to provide their developing country counterparts with access to finance and clean technologies that would enable them to achieve substantial reductions in emissions in a cost-effective fashion.[19,79] It would also involve the revenues from border adjustment measures being earmarked for developing countries as a means of compensation for the foregoing of export revenues.[6] Such carbon levies would typically be directly collected by the exporting country itself in the form of export duties, or recycled back to them in the case they are collected by the importing country in the form of border tariffs.[19] While this could largely alleviate competitiveness concerns and address equity discrepancies, explaining to EU or US public opinion why they need to directly finance infrastructure or capacity projects in China or India might prove problematic.[21]

### Border Trade Adjustments and the Trade Regime

Another problem that would require tackling with in the eventuality of border trade adjustments on carbon embedded in imported goods relates to their compatibility with World Trade Organization (WTO) provisions. A core principle of free trade is that of nondiscrimination between foreign and domestic 'like' products. Countries are not allowed to restrict imports of 'like' products on grounds of environmental impact, such as for example their greater embodied emissions. Exemptions exist, with the protection of global resources being stipulated as such in Article XX of the General Agreement in Tariffs and Trade (GATT). Given their impact on competitiveness and trade patterns, the survival of border adjustments in WTO disputes could therefore hinge on whether or not such measures are designed in such a manner as to pass the environmental effectiveness test. A number of legal conditions need to be met and as Droege[55] notes, there is no guarantee that anti-leakage measures will benefit from Article XX provisions.

The literature does tackle the question of whether it is theoretically possible to put in place WTO-compatible border adjustments. Helm *et al.*,[82] for instance, provide a list of features that could enhance the prospects of a well-designed border adjustment complying with international trade regulations. Elements in their list include *inter alia* the setting up of a system in which foreign and domestic producers alike are subject to the same requirements (e.g., are both part of an EU-like ETS) or 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 (p. 389). Carbon equalization measures, like the principle of 'best available technology' have also been proposed.[91] However, Sakai and Barrett[92] argue that these measures could significantly undermine the effectiveness of border adjustments by reducing the tariffs faced by exporting countries. Given there has been no precedent of a carbon adjustment being challenged in the WTO, we cannot move beyond the confines of a theoretical discussion.[55] Consequently, Lininger[19] concludes that the only way a CB system could be securely put in place and pass the WTO test is not via unilateralism but through an international agreement.

## Nontrade Measures to Address Emissions Embodied in Trade

As alluded to already, alternative and potentially complementary means of mitigating leakage mentioned in the literature include the extension of EU ETS-type schemes, as well as augmenting worldwide technology transfer cooperation.[10] Springmann[4] concluded that an equivalent emission reduction to border tax adjustments could be achieved by linking emissions trading schemes, whereby emissions are capped and carbon allowances within this bought and sold between sectors, across Annex I countries. Such an approach would yield greater welfare benefits for non-Annex I countries and would have more political traction than implementing carbon tariffs on energy-intensive goods imported from non-Annex I countries. Carbon pricing is an efficient policy instrument under any accounting scheme. In the form of an ETS though, it is only in effect in some countries or regions. The EU is such an example, but a low carbon price in the EU ETS, explained largely by economic activity,[93] has deemed it somewhat environmentally ineffective. Price stability would need to be improved to avoid price fluctuations and instability, while sector coverage would also need to be extended to capture more emissions. In the longer term, the EU ETS could link to emissions trading schemes in non-Annex I countries.[4] China, for example, is currently preparing for the launch of its nationwide emissions trading scheme in 2016, while South Korea has already done so since January 2015.[94,95] However, these could also fail to achieve emissions reduction expectations if price changes distort trade patterns, as identified by Jakob and Mashinski,[12] and referred to under effectiveness concerns. Moreover, it is important to recognize that linking emissions trading schemes would lead to a larger, but still not global, carbon market. Consequently, dealing with imported emissions and addressing competitive concerns would remain as important matters.

A second policy option could be to better utilize domestic performance standards by including embodied impacts. Standards have already been successful in reducing emissions in the operation of vehicles, buildings, and appliances.[96] Materials are carriers of industrial energy and a reduction or substitution of material throughput could reduce domestic and internationally traded emissions. By ensuring that only those products within a specified resource performance bracket are sold on the market, regulated standards could ensure a certain level of resource efficiency. This is already implemented for energy through, for example, European policies, including the EU Ecolabel and Eco-design directives, without imposing a tax on imported goods. Performance standards can play a key role, particularly when consumers have limited knowledge or influence over product choice, like for example when renting a house, in which case tenants have limited influence over the products in it. Taking the example of buildings, a lot of research shows that emissions embodied in building fabrics are becoming an increasing proportion of building-related emissions. Whilst existing standards relate to operational energy efficiency addressing mainly production emissions (e.g., gas combusted to heat a home), methods for carbon footprinting have been developed into standards to enable calculation of the embodied emissions of products which are not restricted to domestic operational emissions.[97–99] These, however, will need to consider the relationship between embodied and direct energy; for example, when is it optimal to replace an older inefficient car with a new one that requires energy to manufacture.[100] Material substitution and optimization are potential avenues through which to reduce embodied emissions.[101–105] Similarly, standards could be useful when it comes to nonenergy related products, such as financial services, which produce few direct emissions and are therefore largely neglected in climate policy, yet have a high embodied content.[34] A note of caution is due here though, as such emissions effectiveness of efficiency measures can be diminished by rebound effects.[106] As Sorrell[106] points out, these are extremely difficult to calculate, but the best available evidence suggests that they are higher than previously thought and can offset or eliminate savings from energy efficiency by more than 50%.[107]

Moving on, a third mitigation policy option could relate to changing consumption patterns, given that consumption is the main driver of global emissions. Girod *et al.*[38] suggest that reduced consumption addresses carbon leakage as it reduces embodied emissions. Moreover, as it affects domestic and imported products equally, it has a lower effect on international competitiveness. There is a growing body of literature to show that reduced consumption, through mechanisms such as working less, does not necessarily mean reduced quality of life.[108] Girod *et al.*[38] show the potential of consumer changes in food, shelter, mobility, goods, and services to make a significant contribution to the international 2 degree target. Consumption considers not only energy demand, but demand for material goods and services which can have a high embodied impact. For example, Barrett and Scott[109] show the potential for resource efficiency measures to contribute to reducing consumption emissions. Strategies include material substitution,[110] product longevity[111] and product-service systems.[112] Extending the scope of climate policy to other areas such as resource efficiency increases the coverage of emissions beyond those from a country's production.

Fourth, carbon footprints could play an important role, as they have been used to label products and develop carbon calculators in the hope that they will incentivise consumers to purchase and adopt greener products and lifestyles.[113,114] They have also been suggested to create positive competition between companies to strive for a better carbon label, including companies outside the consuming country.[115] In terms of effectiveness, however, the evidence for information as a standalone mechanism to reduce emissions is inconclusive,[115] with some suggesting it has limited impact[51] unless used in combination with other measures such as obligatory standards.[96] For example, carbon labels are needing to compete with the billions spent on advertising, stimulating demand for consumer goods.[116,117] Practically, it is argued in the literature that the standardization of product footprinting would need to be improved to move from the voluntary reporting of embodied emissions to enable the regulation of embodied performance standards.[118] Politically, standards would also need to comply with trade regulations that prohibit discrimination against the import of similar products, which could be a contentious issue if only some countries were subject to greener standards.[115]

Fifth, public procurement can also play a role, given public spending on goods, services, and works accounts for around 17% of GDP in OECD countries.[119] By exercising buying standards and specifying green criteria systematically in public tenders, governments can provide a stimulus for eco-innovation along product supply chains.[119–123] This requires organizational resources, and hence political support, clear guidelines and training, standardized accounting methods, and increased cooperation with suppliers.

Finally, voluntary agreements can at least be a starting point to engage with international suppliers. For example, Sweden set up a Centre for Environmental Technology (CENTEC) at their Embassy in Beijing, promoting and facilitating exchange of 'envirotech' in public and private sectors.[51] By providing cooperative technology assistance, Sweden is able to influence the carbon intensity of its imports and indirectly introduce consideration of embodied emissions into bilateral policymaking without placing a domestic restriction on imports which could damage demand for developing country products. The host country is able to benefit from the efficiency improvement, which should also improve economic growth.[124]

## CONCLUSION

CB emissions have received considerable attention in the literature in recent years, stimulated largely by the perceived deficiencies of the currently applied PB accounting methodology. This paper presented the case in favor of adopting the CB accounting approach, as well as the arguments against. The overall purpose was to tackle the question whether CB accounting has a future or not. The short answer is that the established PB accounting model is unlikely to yield its place any time soon to its more controversial CB accounting alternative. Thus, CB accounting will not be relevant to the larger (international) scale and, in this sense, it won't have a future. That said, it could provide the international community with an invaluable tool for understanding emission patterns in detail and informing the design of the requisite policies to address these emissions that are embodied in trade.

Acknowledging the predominance of the PB accounting model, this article concluded by outlining some options, relying on readily available policy instruments, such as emissions trading, that could directly or indirectly address the impacts of internationally traded emissions in a more practical and politically acceptable fashion. The climate change regime has gradually evolved into a prime example of an ossifying process that continuously receives new technical or scientific input but consistently fails to act on it.[125,126] Arguing in favor of substituting

PB accounting with CB accounting would most probably meet a similar fate. A step-by-step approach to dealing with CB emissions could constitute a more politically amenable narrative that could be more easily embedded into the design of the future climate architecture.

To conclude, in undertaking this exercise, a number of gaps in the literature were identified that merit further scrutiny. First, the literature on 'shared-responsibility' options is still in its infancy. While Lenzen *et al*.[65] and Andrew and Forgie[44] have offered some examples of shared-responsibility schemes, more work is required to examine the potential implications of moving toward a middle-ground, especially from a global perspective. Whilst the purpose of mandatory monitoring of CB emissions is clear—to prevent the offshoring of emissions to countries without emissions targets, so as not to undermine global mitigation efforts—the institutional framework to enable countries to function in such a system needs developing. Second, a similar problem is encountered when it comes to the literature on full CB schemes. Here, the existing studies are equally scarce. Although the authors that have conducted them generally seem skeptical about the effectiveness of a full CB accounting system, further research is needed to shed light on the debate.

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