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Should carbon-exporting countries strive for consumption-based accounting in a global cap-and-trade regime?

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Abstract

In the context of the post-Kyoto policy debate, the question was raised whether the current practice of production-based emissions accounting should be replaced by a consumption-based approach. In this paper, we qualify the conditions under which the way of carbon accounting makes a difference, and show how this affects the incentive of countries to opt for one or the other alternative. Two main insights are presented: First, it is emphasized–and formally shown with a general equilibrium trade model–that the way of accounting has neither *efficiency* nor *distributive* effects in the presence of a global cap-and-trade regime with full coverage and given national emission caps. Second, the accounting scheme does matter whenever the initial allocation rule for emission rights is related to past emissions. However, for a net exporter of carbon such as China, the preference for one or the other turns out to be ambiguous, since the current production-based accounting would be favored under grandfathering, whereas consumed carbon would be the preferred measure whenever higher current or historic emissions imply a lower initial allowance, as e.g. under the principle of historical responsibility.

Keywords: Climate Policy, Post-Kyoto, Emissions accounting, Consumption-based emissions, Greenhouse-gas inventories

Introduction

The current practice for reporting a country's greenhouse gas (GHG) emissions is to count all emissions that were generated on its territory over a given time period. That is, emissions are attributed to countries according to where they were physically produced. However, in the course of the intense discussions about a post-Kyoto climate agreement and the appropriate role of developing and developed countries therein, the question was raised whether the practice of production-based accounting should not be amended. Arguably, this debate was largely triggered by China's massive export of embodied carbon to Annex I countries, which made up roughly one third of its total carbon footprint in 2005 (Weber et al. 2008; Guan et al. 2009).

As a consequence, several authors have argued in favor of consumption-based accounting, mostly on the grounds of increased effectiveness (Peters and Hertwich 2008a,b; Pan et al. 2008) and equity (Munksgaard and Pedersen 2001;

Bastianoni et al. 2004; Yunfeng and Laike 2009; Lin and Sun 2010). For instance, Yan and Yang (2010) emphasize that those "*who consume goods […] should also share the responsibility*", and recommend China to "*claim [a] consumption based accounting system*" in the global climate negotiations, which would be a "*fairer method of allocating responsibility for GHGs*".

Statements like this point at the potential relevance of the accounting approach for the prospects of post-Kyoto climate policy. In fact, most of the literature explicitly or implicitly suggests that the adoption of consumption-based accounting would lower the threshold for developing countries to join a new global agreement. E.g., according to Pan et al. (2008), "*consumption accounting is also likely to enhance the scope to bring developing countries into an effective post-Kyoto framework*".[1] Likewise, Peters and Hertwich (2008a) argue that countries with a significant share of carbon-intensive exports are deterred from "*participation in binding emission reductions since deep emissions cuts would ultimately affect export industries*".

These arguments for a consumption-based approach imply the existence of significant distributional effects in relation to the accounting method, in particular for exporters of carbon-intensive goods, such as China. However, in view of the large number of competing proposals for a post-Kyoto framework (e.g. Bodansky 2004), it is not clear whether these assertions hold in general, or just for specific types of policy architectures. Namely, a new agreement might be fragmented, i.e. with incomplete participation, leading to different carbon prices (or none) across countries, or with full coverage and participation, resulting in a uniform price of carbon, such as under a global cap-and-trade accord, as proposed, e.g. by Stern (2009).

In this contribution, we qualify the assertions from above by (a) showing that in the latter case of global cap-and-trade, production- and consumption-based accounting are equivalent for given national caps and (b) showing that even where distributional effects can be expected for setting national caps, the preference of a carbon-exporter for one or the other approach is not obvious. Result (a) is derived by means of a general equilibrium trade model, which essentially confirms economic intuition and therefore might not appear imperative, especially not to economists familiar with trade theory. However, our main point is not the formal result as such, but its relevance in the context of climate policy, where in our view it has been underappreciated.

Formal Analysis: Description and Findings

The Kyoto Protocol assigns emission caps only to developed countries, and allows developing countries to participate voluntarily through the Clean Development Mechanism (CDM). In contrast to this, we assume a global agreement assigning legally binding emission caps to all countries with significant carbon emissions for the following analysis. This does not necessarily mean that all countries incur costs, or that all have to reduce their current emissions, as initial allocations might

[1] See also Wang and Watson (2008): "A consumption-based emissions account might also help to make it easier for developing countries such as China to participate in an international post-2012 climate agreement".

be abundant for some countries and emission permits are tradable. Total global emissions will however be capped, e.g. based on a global budget approach as proposed by WBGU (2009).[2]

Within a general equilibrium trade model (formal details below), it can be shown explicitly that in a global cap-and-trade system with given emission caps, switching from a production- to a consumption-based accounting system has neither efficiency nor distributive effects. The distribution of welfare depends solely on the initial allocation of emission allowances among countries, i.e. a binding target of 500 $MtCO_2$ always implies the same level of welfare for a given country, be it under a production- or consumption-based system. Intuitively, this can be explained by the fact that in the presence of a *global* carbon market, costs of emissions will always be internalized and consumers thus always face the same net consumer price.[3] The initial allocation of permits matters because it generates income for countries in form of a scarcity rent. However, once the allocation issue is settled, the choice between production- or consumption-based accounting has no influence on the welfare of countries, irrespective of being net exporters or net importers of emissions.

Under conventional *production-based* accounting, all firms producing an identical[4] good include their individual emissions as additional input factor in production costs, but–in equilibrium–sell their good at the common international market price, independent of its specific carbon content. If a country is a net exporter of emissions, it uses the permits of its initial allocation and, possibly, buys additional permits from other countries. The emission costs, however, are still internalized in the price of goods when they are exported. Thus, in the end the importing country's consumers implicitly pay for the embedded emissions.

With *consumption-based* emissions-accounting, international prices of identical goods would in theory be different whenever they contain different amounts of embodied carbon. In equilibrium, however, producer prices of identical but more carbon intensive goods adjust, becoming lower than those of low-carbon substitutes, so as to lead to a uniform net consumer price. Since consumers have to buy more permits for goods with higher carbon content, producers' profits are reduced in accordance to their specific carbon intensity by receiving a smaller share of the revenue.

Hence, in both cases production conditions are altered due to the emissions constraint, either explicitly (production-based accounting) or indirectly through market forces (consumption-based accounting). This explains why the two different systems have no influence on the efficiency of production. In addition, they also have no influence on the welfare distribution, since in both cases the complete internalization of emissions means that the associated costs are ultimately borne by consumers.

[2] Arguably, this constitutes a strong assumption. However, almost all studies that analyze pathways to atmospheric GHG stabilization foresee the adoption of binding targets for developing countries at some point in time, e.g. Richels et al. (2009).
[3] A similar effect is known from tax theory, where the point of taxation–on the consumer or on the producer side–has no impact on efficiency (Salanie 2002).
[4] We call goods *identical* if they are perfect substitutes in the utility function of the consumer.

Relevance of Results and Discussion

In light of our results, the question of which accounting scheme is preferable for a global cap-and-trade system can be separated from distributional aspects. However, there are other differences between the two accounting schemes that may be relevant: For instance, consumption-based accounting could require considerable resources for determining and labeling the embodied emissions in every stage of the production process and all final consumption goods. Moreover, the quantification of the carbon content of trade is still prone to methodological uncertainties (Liu and Wang 2009), suggesting that in terms of transaction costs and environmental effectiveness the current accounting based on production would be favored (Wang and Watson 2008).

Developing countries, in particular, insist that a global climate policy framework must be based on the principles of equity and reflect the UNFCCC principle of common but differentiated responsibilities. Following our argumentation, in a global cap-and-trade framework equity can be addressed by means of appropriate burden sharing rules, which allow to incorporate different responsibilities of countries through different initial allocations of emission allowances.

In the past, different principles that may guide this initial allocation were proposed (e.g. Baer et al. 2000). Among others, emissions could be allocated (i) on an equal per-capita basis, (ii) by grandfathering, or (iii) by the principle of historical responsibility, which allocates a higher cap to countries with lower cumulative historical emissions. In this context the two accounting schemes can diverge: whenever past emissions are used to determine a specific allocation (ii and iii), production- and consumption-based accounting will lead to different distributional outcomes. In the case of grandfathering, countries that are net exporters of emissions benefit from production-based accounting, because it implies a higher initial cap. Conversely, if countries' historical emissions lead to a diminution of the allocation–as in (iii)–net exporters benefit from consumption-based accounting. The choice of the accounting scheme can thus have a significant impact on the allocation of emission allowances, and thereby on the distribution of mitigation costs. By contrast, allocating emissions on an equal-per-capita basis is independent from past emissions and, thus, from the accounting method. In other words, a large share of exports in emission-intensive production does not automatically lead to a preference for a specific accounting method; rather, the preferred method will depend on the initial allocation scheme.

Taking China as example, it would be better off in a global carbon market with production-based accounting, if emission certificates were grandfathered like under the Kyoto Protocol. Namely, assume China was to join a global cap-and-trade system from 2020 on, and be given an annual emission allowance equal to its 2005 emissions. Following Lin and Sun (2010), China had production-related emissions of 5.5 $GtCO_2$ in 2005, which lowers to 4.4 $GtCO_2$ for a consumption-based measurement. [5] Accordingly, under a grandfathering rule, the cap for China would be 1.1 $GtCO_2$ higher for production- than for consumption-based accounting, thus implying relatively lower mitigation costs. Similar considerations arise for an allocation based on historical responsibility: As those who have

[5] Consumption based emissions follow from Table 5 in Lin and Sun (2010) as the difference between total emissions and 'net embodied emissions of trade balance' EEB.

emitted relatively less in the past would be allocated larger allowances for the future, China–assumed to be a net exporter of carbon in the past–would receive relatively more emission permits under consumption-based accounting. For an equal-per-capita allocation, however, the national cap would only depend on China's share of the world population and on the negotiated global emission cap, resulting in the same outcome under both accounting schemes.

Our assumption of global cap-and-trade might seem a strong and for the near future unrealistic restriction. In fact, without global coverage, international carbon leakage becomes a problem, as becoming evident for the Kyoto Protocol (Dröge et al. 2009). Whether consumption-based accounting could be better suited to control carbon leakage than production-based accounting is a relevant question, which is addressed in several contributions (e.g. Peters and Hertwich 2008a,b; Pan et al. 2008), and still needs further research.

Formal Analysis

In this section we use a general equilibrium model to formally demonstrate the equivalence of the two accounting schemes under global cap-and-trade. Although in hindsight the model mostly confirms economic intuition, it helps to make the relevant mechanism explicit.[6] We start by considering two countries, A and B (superscript index *i*), and two sectors, 1 and 2 (subscript index *j*).

Each country is characterized by transformation functions $q_2^i = T^i(q_1^i)$, which describe the efficient combinations of output in goods q_1^i and q_2^i. Emissions arise as a byproduct of production and are proportional to output, with fixed specific emission intensities $\gamma_j^i \geq 0$. Accordingly, total production-based emissions of country *i* are given by $E^i = \Sigma_j \gamma_j^i \; q_j^i$.

Preferences of the representative consumers are expressed by a generic utility function $U^i(c_1^i, c_2^i)$, where c_j^i is country *i*'s consumption of good *j*. Goods can be differentiated according to their origin by using the notation im_j^i, which indicates country *i*'s imported consumption of goods of type *j* with foreign origin.

We now compare the two different emission accounting schemes by considering the associated competitive equilibria in goods and emission permits. Note that in both cases we assume the presence of a global cap-and-trade regime, with a total cap *Z*, of which each country *i* receives Z^i permits (for free) as initial allocation.

Under **production-based accounting,** each country faces the following optimization problem: given prices p_j and τ of goods and permits, choose the point of production and consumption such that utility is maximized:

$$\max_{\{q_1^i, c_1^i, c_2^i\}} U^i\left(c_1^i, c_2^i\right) \quad . \qquad (1)$$

[6] In its way of including emissions, it also differs from the standard approach in trade modeling.

Any solution must satisfy the budget constraint, which ensures that total expenditure equals total income,

$$p_1\ c_1^i + p_2\ c_2^i = p_1\ q_1^i + p_2\ q_2^i + \tau\left(E^i - Z^i\right)\ , \tag{2}$$

and be physically feasible, i.e. $q_2^i = T^i(q_1^i)$. The two constraints can be combined by writing the budget constraint as

$$p_1\ c_1^i + p_2\ c_2^i = \left(p_1 - \tau\ \gamma_1^i\right)q_1^i + \left(p_2 - \tau\ \gamma_2^i\right)T^i(q_1^i) + \tau\ Z^i\ . \tag{3}$$

Eqs.(1) and (3) define a well-posed general equilibrium problem, since the optimization determines the choice variables of both countries as functions of p_i and τ, while the latter are found by using the market clearing conditions for goods and permits.

In the case of **consumption-based accounting**, goods must be differentiated according to their origin, since they generally require different amounts of emission permits per unit of consumption. Therefore, four different prices for goods have to be introduced, where p_j^i is used to denote the price of good type j produced in country i. It is helpful to also define price differentials Δp_j^i, which stand for the difference in the price of good j from the point of view of country i, e.g. $\Delta p_1^B = p_1^B - p_1^A$.

Countries now maximize their utility according to

$$\max_{\{q_1^i, c_1^i, c_2^i, im_1^i, im_2^i\}}\ U^i\left(c_1^i, c_2^i\right)\ , \tag{4}$$

with a budget constraint formed by the equalization of expenditure and income

$$p_1^i\ c_1^i - \Delta p_1^i\ im_1^i + p_2^i\ c_2^i - \Delta p_2^i\ im_2^i + \tau\ E_C^i = p_1^i\ q_1^i + p_2^i\ T^i(q_1^i) + \tau\ Z^i\ . \tag{5}$$

Here, E_C^i represents the consumption-based emissions of country i, which–using $\Delta\gamma_j^i$ to denote the intensity differentials in an analogous way as Δp_j^i for prices–can be written as

$$E_C^i = \gamma_1^i\ c_1^i - \Delta\gamma_1^i\ im_1^i + \gamma_2^i\ c_2^i - \Delta\gamma_2^i\ im_2^i \tag{6}$$

Combining the last two Eqs.(5) and (6) allows writing the maximization constraint as one equation

$$\left(p_1^i + \tau\, \gamma_1^i\right) c_1^i - \left(\Delta p_1^i + \tau\, \Delta\gamma_1^i\right) im_1^i + \left(p_2^i + \tau\, \gamma_2^i\right) c_2^i - \left(\Delta p_2^i + \tau\, \Delta\gamma_2^i\right) im_2^i$$
$$= p_1^i\, q_1^i + p_2^i\, T^i(q_1^i) + \tau Z^i \tag{7}$$

which precisely shows how the sum of the (producer-) price for goods and for emissions forms the net price faced by consumers. To determine all prices, the market clearing conditions for emission permits and for all (four) goods are used.

For a formal solution of the optimization problem defined by Eqs.(4) and (7), the appropriate *Lagrangian* L^i is formed. Let us consider the optimal choice for im_j^i, which only appear in the budget constraint Eq.(7). Therefore, the first-order conditions for an interior solution are simply given by

$$\frac{\partial L^i}{\partial im_j^i} = 0 = \Delta p_j^i + \tau\, \Delta\gamma_j^i \quad , \tag{8}$$

which directly implies

$$p_j^A + \tau\, \gamma_j^A = p_j^B + \tau\, \gamma_j^B \quad . \tag{9}$$

The intuition behind this equation is straightforward: in a competitive trade-equilibrium the net consumer prices (compare with Eq.(7)) for all identical goods must be the same, since otherwise consumers would buy only the cheapest 'version'. This implies that of the four prices p_j^i two, say p_j^B, are already determined. Let us now substitute the two unknown prices p_j^A by new unknowns called cp_j ('consumer price'), according to

$$p_j^A \equiv cp_j - \tau\, \gamma_j^A \quad . \tag{10}$$

By inserting cp_j into the budget constraint Eq.(7) and using Eq.(8) one obtains

$$cp_1\, c_1^i + cp_2\, c_2^i = \left(cp_1 - \tau\gamma_1^i\right) q_1^i + \left(cp_2 - \tau\gamma_2^i\right) T^i(q_1^i) + \tau Z^i \quad . \tag{11}$$

The 'size' of the optimization problem has been reduced to only two consumption goods and two prices. In fact, a comparison with Eq.(3) shows that it is equivalent to the one where emissions were accounted on the basis of production. Thus, we have shown that both accounting schemes would lead to the exact same production and consumption levels.

Concluding Remarks

Under a global cap-and-trade system with full coverage and given initial allocations, production- and consumption-based accounting are equivalent in terms of efficiency and distributional effects. Therefore, they should in this case be assessed on the basis of other aspects, such as transaction costs. With regard to initial emission allocations and the underlying principles of burden-sharing, the choice of the accounting scheme will make a difference whenever past emissions influence the allocation decision. Ethical reasons may justify consumption-based counting of past or current emissions, but for a future global carbon market the expected lower transaction costs speak in favor of production-based accounting.

In view of our results, one possible way for building up an effective, efficient, and fair cap-and-trade regime would be to choose–in accordance with some underlying ethical principle–a specific production- or consumption-based allocation method for the computation of national caps, and to implement the associated system of emissions trading on the basis of production-based accounting.

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