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A comparison of carbon allocation schemes: On the equity-efficiency tradeoff

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ABSTRACT

In the long-term stabilization targets of greenhouse gases concentrations, various carbon emission rights allocation schemes have been proposed. To compare and evaluate them, the most essential is the equity-efficiency tradeoff. This paper measures the equity and the efficiency in the global rather than the narrower national perspective. Specifically, the equity of the first allocation is quantified by the carbon Gini coefficient defined by per capita cumulative emission, and the economic efficiency to accomplish obligations is described with the discounted global abatement costs. Under 20 key allocation schemes, the numerical comparison on the equity-efficiency tradeoff side is carried out through the Equitable Access to Sustainable Development model. Our studies indicate that the equity and the efficiency of future emission space allocation approximately show a three-stage relationship.

1. Introduction

Global climate change induced by the excessively anthropogenic emissions of GHGs (greenhouse gases) has become a great threat to the future development. As a solution, the UNFCCC (United Nations Framework Convention on Climate Change) has affirmed that GHGs concentrations in the atmosphere should be stabilized at a level that would prevent dangerous interference with the climate system [1]. To meet this ultimate objective in the long term, future emission space will be extremely restricted.

The severe stabilization targets admittedly require a global participation and cooperation. All countries have to control and reduce their current and future GHGs emissions. In order to achieve collective efforts (or reach an agreement) in the global scope, a series of carbon emission rights allocation schemes have been put forward in either resource-sharing or burden-sharing perspective. Based on different criteria, they are intended to allocate stringent global emission space among countries in a top-down or bottom-up manner. With these schemes, the global targets can be concretely disaggregated to emission allowances (or reduction obligations) of individual countries. In accordance with common but differentiated responsibilities and respective capabilities [1], a rational threshold (e.g. per capita GDP (gross domestic production), per capita emission, a pre-defined start year or a responsibility-capacity index) can be introduced to determine the gradual participation of developing countries in quantified commitments, as summarized in Table 1 [2–6].

Since emission rights will drastically affect all countries' interests, Article 3.1 of UNFCCC has emphasized that mitigation efforts should be shared on the basis of equity [1]. From the qualitative view, the equity is an ambiguous and debatable concept. In the literature, the equity is often discussed in the ethical perspective, and four key principles of allocation equity have been recognized, i.e. egalitarian, sovereignty, responsibility and capability [7,8]. All rule-based schemes listed in Table 1 can be characterized by the four principles. Besides the equity, Article 3.3 has also stated that it should be cost-effective to cope with climate change so as to ensure global benefits at the lowest possible costs [1], i.e. the efficiency. To discuss it, the estimation of accompanying abatement costs is immediately needed. On one branch, some works directly calculate costs with integrated assessment models or cost economy models, e.g. C. Kemfert et al. [9] utilized the Climate Framework for Uncertainty, Negotiation and Distribution model, and T. Ekholm et al. [10] employed the Integrated MARKAL-EFOM System Integrated Assessment Model. On the other branch, numerous studies over the last two decades have been performed with MACs (marginal abatement cost curves) derived from models.

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Table 1
Carbon emission rights allocation schemes.

Group	Scheme	Abbr.	Threshold (Y/N)
Basic schemes	Equal per capita annual emission scheme	EPC	N
	Contraction and convergence	CC	N
	Grandfathering rule	GF	Y
	Brazilian proposal	BP	N
	Ability to pay scheme	AP	Y
Variants	Adjusted equal per capita annual emission scheme	AEPC	N
	Indian prime minister's proposal	IPM	Y
	Common but differentiated convergence	CDC	Y
	Emission intensity convergence	EIC	N
	Historical responsibility scheme	HR	Y
Weighted schemes	Preference score approach	PS	Y
	Convergence scheme proposed by Centre for Science and Environment	CSE	N
	Multi-criteria convergence	MCC	Y
Stages/groups	Multi-stage scheme	MS	Y
	Emission intensity targets scheme	EIT	Y
	South-North dialog approach	SND	Y
Sector emissions	Multi-sector convergence	MSC	N
	Triptych approach	TT	N
Individual differences	Greenhouse development rights framework	GDR	N
	South African approach	SAA	N
	One billion high emitters scheme	BHE	N
Cumulative emissions	Equal per capita cumulative emission scheme	EPCCE	N
	Carbon budget proposal	CB	N

For instance, Ellerman and Decaux [11], Morris et al. [12] extracted MACs from the Emissions Prediction and Policy Analysis model with emission constraints. Criqui et al. [13] produced MACs from the Prospective Outlook on Long-term Energy Systems model with carbon taxes.

In the field of energy, a few studies have already considered the economic efficiency or the equity issues [14–17]. The Coase theorem [18] states that in the absent of transaction costs, the trade mechanism (bargaining) will always results in an efficient outcome regardless of the initial allocation of property. However, in more general cases, the tradeoff between the equity and the efficiency should be carefully considered by the policy makers. Some researches in related areas have already discussed this tradeoff issue. For resource allocation in operations management, D. Bertsimas and V. F. Farias [19] proposed a framework where they adopted a utilitarian criterion and an inequality aversion as measures of the efficiency and the equity, respectively. For policy evaluation in environmental economics, S. Dietz and G. Atkinson [20] used a simple choice experiment to elicit individual preferences. I. H. Correia [21] developed a methodology to identify whether a certain policy leads to an efficiency-equity tradeoff. L. Shiell [22] analyzed the equity and the efficiency in the international market for pollutants. An important conclusion made is that since the derivation of Pareto efficient highly depends on the ability to measure marginal willingness to pay which still remains limited, the only practical guide for policy at present appears to be cost-effectiveness. For global climate change, several studies plan to balance the equity and the efficiency. P. R. Shukla [23] qualitatively investigated the justice, equity and the efficiency in climate change from the standpoint of developing countries. S. Aakre and T. G. Rubbelke [24] proposed a framework for European Union adaptation policy that addressed the equity and the efficiency concerns. A. S. Manne and G. Stephan [25] provided some insights into the equity-efficiency tradeoff and pointed out that if all the costs of climate change could be expressed in GDP losses, Pareto-efficient abatement strategies would be independent of the initial emission rights allocation; otherwise, different sharing rules might affect the optimal levels of GHGs reductions. It should be noted that these studies have been mainly used a small-scale mathematical model based on the utility theory and welfare economics. With the equity considerations incorporated, they usually try to find an efficient allocation or strategy in combating climate change.

Different from the studies mentioned above, we don't strive to create an equity-efficiency balanced methodology or distribution, which in reality should be the motive of international climate negotiations. This paper focuses on the comparison among the emission rights allocation schemes that have been proposed in the international community, and aims to analyze the equity-efficiency tradeoff behind them. The remainder of this paper is organized as follows. Section 2 puts forward integrated indicators to measure the allocation equity and the fulfillment efficiency. Section 3 presents the study tool, i.e. the EASD model (Equitable Access to Sustainable Development). Section 4 implements the equity-efficiency tradeoff analysis. Finally, Section 5 provides the conclusions.

2. Aggregated indicators

It is primarily noted that as the whole world should work together to address climate change, we will conduct the following analyses from the global but not the national or regional perspective. The global aggregated indicators to measure the equity and the efficiency will be first presented in this section.

2.1. Equity

A potential scheme should basically make most countries believe that they are equitably treated. There have been many works discussing the symmetry of adaptation, benefits, losses and damages in addressing climate change [26–29]. Although the analysis of equity has already widened to include impacts, adaptation and support, the central concern remains mitigation (effort sharing) [30]. In this case, the essence of the carbon allocation equity should rationally spell out the differences in the carbon space distribution. However, existed studies haven't paid enough attention. And instead of an objective measurement, they just attempt to reflect the equity by comparing emission allowances of main parties under UNFCCC. Ruijven et al. compared the allowances of China and India under 10 allocation approaches [31]. A comprehensive survey of over 30 effort-sharing studies on emission allowances of 10 regions in the world is recently conducted by Hoehne et al. [32]. Only several studies have tried to quantitatively describe the carbon equity in the distribution of current emission space. These studies have been all referred to the inequality measure in income distribution and carried out in the view of per capita annual emission. For instance, Hedenus and Azar [33] adopted the Atkinson index to evaluate the inequality of per capita emission among countries. Padilla and Serrano [34] applied the Theil index to study the inequality in CO_2 emissions and its relationship with income inequality. Heil and Wodon [35] analyzed emissions inequality using a group decomposition of the Gini coefficient. The scientific measurement of the allocation equity is no doubt crucial for all countries to preserve their necessary and reasonable emission rights in the future and promote the realization of the global carbon equity. Unfortunately, no preview studies have formally