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Allocating CO_2 allowances to emitters in China: A multi-objective decision approach

Bangzhu Zhu[a,*], Mingxing Jiang[a,*], Kaijian He[b], Julien Chevallier[c,d,**], Rui Xie[e]

[a] Business School, Nanjing University of Information Science & Technology, Nanjing 210044, China
[b] School of Business, Hunan University of Science and Technology, Xiangtan 411201, China
[c] IPAG Business School, IPAG Lab, 184 Boulevard Saint-Germain, 75006 Paris, France
[d] Université Paris 8, LED, 2 avenue de la Liberté, 93526 Saint-Denis, France
[e] College of Economics and Trade, Hunan University, Changsha 410082, China

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ABSTRACT

China CO_2 allowance (CHA) allocation for emitters is one of the pivotal issues to build the effective national carbon market. In this study, we propose a multi-objective decision approach, incorporating the principles of fairness, efficiency, and feasibility, to allocate the CHAs to emitters from the industry perspective. Taking Guangdong, China as an example, we employ the proposed approach for allocating the CHAs to six major industries of petrochemical, chemical, cement, steel, nonferrous metals, and electricity power by 2030. The empirical results show that there are significant conflicts between principles. The proposed approach can not only effectively eliminate the defects of single-object models to make the allocation results more reasonable and acceptable, but also achieve optimal allocation options under various decision preferences. The power industry has the highest CHA and petrochemical industry has the lowest one, and petrochemical, chemical, and steel industries have the greatest potential to reduce carbon intensity. Single-factor sensitivity analysis shows that the CHA/10^4 Yuan added value (TY) of the industry with lower emissions is more sensitive to the changes of physical capital stock but received fewer impacts from the changes of emissions cap for six industries.

1. Introduction

Global climate change has received increasing attention. As a cost-effective mean to deal with the global climate change, carbon market can reduce CO_2 emissions at the lowest costs. CO_2 allowance allocation is one of the key issues to build an effective carbon market (Jiang et al., 2016). China has become the largest CO_2 emitter in the world and is committed to reducing carbon intensity, which is defined as CO_2 emissions per unit of gross domestic product (GDP). China's targeted carbon intensity by 2030 is to decline 60–65% compared with 2005. In order to achieve the target, China has implemented seven pilot carbon markets and activated national carbon market in 2017.[1] In phase III (2013–2020), European Union Emissions Trading System (EU ETS) allocated the European Union allowances (EUAs) by the "top-down" approach,[2] which composes of two stages: in the first stage, European Union commission allocates the EUAs to the member states. In the second stage, each state allocates its own EUAs to emitters. Likewise, China can adopt this approach to process emissions allocation. In the first stage, the central authority allocates the China CO_2 allowances (CHAs) to each province. In the second stage, each province allocates its own CHAs to emitters. As CHAs allocation in the second phase is the terminal process, it can directly influence the firms' behaviors of production and operation. Intuitively the carbon quotas should be allocated to firms with full consideration of mitigating the shock on the production of firms (it may include employment and other considerations) as well as the fairness and efficiency. Facing the upcoming start of China's national cap and trade program, how to allocate emission

* Corresponding authors.
** Corresponding author at: IPAG Business School, IPAG Lab, 184 Boulevard Saint-Germain, 75006 Paris, France.
E-mail addresses: wpzbz@126.com (B. Zhu), 18588847515@163.com (M. Jiang), julien.chevallier@ipag.fr (J. Chevallier).

[1] Chinese national carbon market was started in December 2017, and the power sector initially proceeded into the market in the trial period. The pilot carbon markets include Beijing, Tianjin, Shanghai, Guangdong, Shenzhen, Hubei and Chongqing.

[2] In phase I and phase II the EUAs ware allocated by national allocation plan (NAP), which can be called "down-top". In phase III, EUAs allocation was handled uniformly, that is no longer national allocation plans with different targets but an almost fully harmonized European instrument. Thus EUAs allocation in phase III is processed by "top-down" pattern.

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permits to emitters has become one of the critical issues facing program designers.

This paper recognizes the fact that decision makers usually do not have singular objectives. They may have multiple objectives and need to structure their analysis accordingly. Therefore, we try to integrate the optimization with comprehensive indicators to build a multi-objective decision approach for allocating the CHAs to emitters from the industry perspective, in which the principles of fairness, efficiency and feasibility are embedded, so as to provide the best allocation results under different decision preferences of decision-makers. The proposed case-study allows verifying the superiority of the proposed multi-objective resolution approach. Overall, our study contributes to building national carbon market and achieving the goal of CO_2 emissions reduction in China.

The main contributions are twofold: firstly, we propose a novel multi-objective decision model to allocate CHAs to emitters from an industrial perspective, which not only can effectively eliminate the defects of single-object models, but also provide the best allocation results under various decision preferences of decision-makers. Secondly, taking Guangdong, China as an example, we employ the proposed model to allocate CHAs to six major industries (petrochemical, chemical, cement, steel, nonferrous metals and electric power). Benchmarks (emissions per added value) of the emitters are obtained. The benchmarks are important references when the authority activates the allocation procedures. Once the benchmarks are decided, the total permits allocated to the firm will be benchmark*added value size.

The rest of this article is organized as follows: Section 2 is a literature review. Section 3 outlines the methods. Data and scenario setting are given in Section 4. Section 5 presents the empirical results and discussions. Section 6 provides the sensitivity analysis. Section 7 concludes and puts forward some policy implications.

2. Literature review

During recent years, numerous studies have concentrated on the allocation principles and methodologies. The principles can be broadly classified into fairness, efficiency, and feasibility. The discussion on fairness criteria is well documented in the literature. Ringius et al. (1998, 2002) make a summary regarding fairness criteria, mainly including sovereignty, egalitarianism, horizontal equity, vertical equity, and polluter pays.[3] The efficiency principle focuses on achieving climate targets by sharing abatement burden with the lowest costs (Cui et al., 2014; De Cara and Jayet, 2011) or maximum economic benefits (Feng et al., 2015; Lennox and Van Nieuwkoop, 2010). In addition, the feasibility principle is also proposed in the existing studies. They argue that the burden sharing formula should be more easily accepted by different participants and easily implemented in practice (Zhou and Wang, 2016; Zetterberg et al., 2012).

The allocation methods can be broadly divided into three types: indicator, optimization and game theory. The indicator methods can be divided into the ones of a single indicator and comprehensive indicators. The single indicator methods assign allowance in term of a measurable indicator, mainly including historical emissions (Böhringer and Lange, 2005; Schmidt and Heitzig, 2014), population (Meyer, 2000; Höhne et al., 2006; Ding et al., 2009), GDP (Rose, 1990; Rose et al., 1998; Rose and Zhang, 2004), outputs (Åihman and Zetterberg, 2005; Böhringer et al., 2014), and carbon intensity (Gupta and Bhandari, 1999; Miketa and Schrattenholzer, 2006). Triptych and multi-criteria decision analysis (MCDA) are the two main comprehensive indicators approaches. Triptych approach (Phylipsen et al., 1998; Elzen et al., 2008; Hof and Den Elzen, 2010) divides the national economic sectors into three groups: domestic sector, energy-intensive and power sector. This approach needs to specify the functions of CO_2 emissions of three sectors, then CO_2 emission allowances for each sector can be calculated based on the estimation of economic growth, demographic change, and CO_2 emissions allowance increment. MCDA is an analysis procedure on how to decide the best from alternative options (Ringius et al., 1998; Vaillancourt and Waaub, 2004, 2006; Leimbach et al., 2010; Yi et al., 2011). Comprehensive indicators methods received increasing attention due to the merit of integrating multiple criteria. As a result, the sharing policy obtained from comprehensive indicators will be more acceptable for emitters compared with the single indicator.

The optimization method uses various operational research models to allocate the CO_2 allowances, including nonlinear programming (Nordhaus and Yang, 1996; Cantore and Padilla, 2010) and data envelopment analysis (DEA) (Feng et al., 2015; Zhou et al., 2014). Furthermore, taking allowance allocation as a process of the multi-stage dynamic game, game theory has been introduced to exploring the optimal allocation mechanism (Eyckmans and Tulkens, 2003; Helm, 2003; MacKenzie et al., 2009; Zhang et al., 2014). We also notice that some studies involve examining allowance allocation at the industry or sector level via different methodologies (Ekholm et al., 2010; Wu et al., 2016), or evaluating the allocation options at industry or sector level (Jensen and Rasmussen, 2000; Stenqvist and Ahman, 2016).

The existing methods in the literature have different characteristics. The single indicator approach is simple, and the results can be easily predictable but with more discrepancy and unreasonableness. More criteria can be considered in the comprehensive indicators method such that the results are more reasonable and acceptable. However, to the best of our knowledge, few publications have explicitly addressed the issues of CO_2 allowance allocation in the second phase (allowances are allocated to the emitters by the states in EU ETS, or by the provinces in China) with comprehensive indicators approach, which are widely applied in the first phase (allowances are allocated to the states by European union commission, or to provinces by central authority in China). Negotiations among the participants in allocation can be fully embodied in the game theory models, but the models are usually complicated and the results are less transparent.

For the sake of simplicity and feasibility, Grandfathering is broadly used in six pilot carbon markets in China (except for Shenzhen market). Baseline method was introduced in phase II of EU ETS and dominant in phase III. However, the grandfathering only embodies feasibility principle, and baseline method only embodies efficiency principle. The models of emissions allocation to emitters should be constructed with combined criteria rather than single one since several essential principles should be taken into account simultaneously. Firstly, allowances allocation to emitters can directly and significantly affect the production of firms (Demailly and Quirion, 2006), which are the most concerned by decision-makers. Secondly, an effective allocation policy should be capable of stimulating firms to reduce CO_2 emissions (Zetterberg et al., 2012), thus it is quite important to design the criteria of fairness, which should take full use of the heterogeneities among industries (firms). Last but not the least, CO_2 allowance allocation methods should be simpler and more feasible (Zhou and Wang, 2016), which means that the method must be easily understood and implemented by decision-makers in practice and facilitate to keep the production consistency of firms.

This paper departs from the existing literature in combining

[3] The criteria have different implications. Sovereignty means that All nations (firms) have equal right to pollute and to be protected from pollution the permits are allocated in proportion to historical emissions. Egalitarianism means equal rights of Human beings to use the atmospheric resources and permits are allocated in proportion to population. Horizontal equity means the countries should be treated with equal net welfare changes and permits allocation should make that net cost of abatement as a proportion of GDP is the same for each country. Vertical equity means greater emissions reduction burden to be carried by richer countries and permits should be progressively distribute in terms of per capita GDP. Polluter pays means that greater abatement burden to be carried by the larger polluter and the abatement burden is allocated in proportion to historical emissions.