

Mixed Allocation Method for Carbon Emission Initial Allowance in Port Industry

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Abstract. Targeting issues in initial allocation of carbon emission allowance in port industry, this study puts forth a mixed allocation method that uses the baseline method for handling production allowance and the historical intensity method for auxiliary production allowance. This study clarifies the organizational boundary and operational boundary using this method, analyzes related factors, and provides the computational formulas. In the instance analysis, the specific calculation process of applying this method to specialized container terminal, specialized dry bulk terminal and general terminal, as well as the value method of basic data and correlation coefficient are given. Compared with the single use of historical intensity method or baseline method for allocation of allowances, although the operation of the mixed allocation method is relatively complicated, it not only considers the historical emission basis of the emission control enterprises, but also achieves a fairer and more reasonable performance by setting the baseline intensity of the loading and unloading production links. This research will help drive port companies to enter the carbon emissions trading markets as soon as possible, playing a promotive role in catalysing sustainable development of port companies.

1 Introduction

1.1 Background

In 2011, a pilot program for carbon emission trading was officially launched in China, with seven provinces/municipalities including Beijing and Shanghai becoming the first to execute the pilot program. In 2017, the preparation for a nationwide unified carbon emission trading market was officially launched, and the national systemic trading rules were published for the first time at the end of 2020. Since the carbon trading pilot program was launched, all pilot regions have focused on high-energy-consuming industries such as electrical power and iron & steel industries, less involving transportation. In various pilot systems, Shanghai has included aviation and ports^[1] while Shenzhen and Beijing have included buses, taxis, rail transit vehicles and stations^[2], however, not many companies have participated. During “the 14th Five-year Plan”, as one of important steps to implement the objective of new peak carbon dioxide emissions and the vision of carbon neutral, carbon emission trading will transform from pilots to the whole country, from single industries to multiple industries, and as one of key fields to deal with climate changes, the transportation industry will be bound to face the topic. As a large and powerful port country, China's port throughput has always ranked first in the world and maintained rapid growth in recent years. Catalysing port companies to join the carbon emission trading system as soon as possible is of great

significance to sustainably grow, transform and upgrade ports.

Allocating carbon emission allowance is an important step in carbon emission trading playing the fundamental role. Here, the rules for allocation of initial allowance shall maximize the efficiency of the allocation process and the fairness of the allocated results^[3]. At present the lack of technical support for initial allowance allocation is one of vital reasons that lots of port companies cannot join the trading system^[4]. Therefore, by drawing on practical experiences in carbon emission trading in pilot regions and other industries at home, and considering the features of energy consumption of the port industry, putting forth an allocation method of the carbon emission initial allowance fit for the port industry is of importance to promote port companies to participate in the carbon emission trading.

1.2 Basic Method

The carbon emission initial allowance allocation includes compensated allocation and uncompensated allocation which was universally used in the early days of implementing the emission trading system. In practice, the uncompensated allocation generally uses the historical intensity method and the baseline method.

(1) Historical intensity method

The emission allowance of an emission-controlling company is determined based on its historical carbon dioxide emission data and the current year's actual

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capacity, with the computational formula shown in Formula (1). The historical emission intensity is:

$$A=B \times F \times Q \quad (1)$$

Where, A is the carbon emission initial allowance, B is the historical emission intensity, which shall be the mean emission intensity of 3 or 4 years before the allocation year; F is the emission-controlling factor, which should be determined in a unified way by the competent authority, with the value of 0~1 in general; Q is the current year's output or capacity of the company.

(2) Baseline method

The emission allowance is checked and ratified based on the industry's reference carbon emission intensity and the current year's actual capacity of the emission-controlling company, with the computational formula shown in Formula (2).

$$A=BM \times F \times Q \quad (2)$$

Where, A is the carbon emission initial allowance, BM is the reference value of the emission intensity, which should be determined and evaluated in a unified way by the competent authority; F is the emission-controlling factor; Q is the current year's output or capacity of the company.

2 Methodology Research

2.1. Carbon Emission Calculation Boundary

The organizational boundary for carbon emission calculation is defined as the handling production systems which are directly used by port companies for handling production and the auxiliary production systems which are directly used serving the handling production^[5]. To be noted, production processes outsourced to a third party shall also be included in the boundary, while the carbon emissions generated by anchored ships from using shore power and thermal insulation of reefer containers are excluded.

The operational boundary for carbon emission calculation is defined as direct emissions generated from fossil fuel burning, and indirect emissions generated from purchased power and heat.

2.2 Influencing Factors

Comprehensively considering division of energy-use systems, handling technology, energy-consuming equipment and the status quo of the energy consumption statistic work of port companies in China, the influencing factors for the mixed allocation method include four categories: basic information, production data, energy consumption data and calculative coefficients, as shown in Table 1

Table 1. Influencing factors

Influencing Factors		
basic data	equipment	type and specification of main energy consumption equipment in each process of handling production
	plane layout	the conveying distances of the

		belt conveyors in each handling process in the dry bulk cargo terminals etc.
production data	throughput	the port throughput assigned in the current year and that in previous 1-3 years
	equipment operation coefficient	the ratio between the operational quantity of each main energy consumption equipment and the throughput
	production proportionality coefficient	the proportions on direct loading and direct delivery, water-water transit, hold cleaning operation and terminal loading/unloading ships
energy - consumption data	energy consumption for handling production	the quantity of physical materials for energy consumption for main energy consumption equipment
	energy consumption for auxiliary production	the quantity of physical materials for energy consumption for auxiliary production
carbon emission calculative coefficient		coefficient for converting each energy resource to standard coal
		fuel lower calorific value, fuel carbon content per unit calorific value and oxidation rate of fossil fuels
		carbon emission factor of indirect emission fuels

2.3 Mixed Allocation Method

The mixed allocation method is to use different methods to allocate initial allowance for the handling production processes and auxiliary production processes based on their different energy-consumption features. See Equation (3) for the calculation formula.

$$E = EU + EA \quad (3)$$

Where,

E - the carbon emission initial allowance for each company (t-CO₂).

EU - the carbon emission initial allowance for the handling production process (t-CO₂).

EA - the carbon emission initial allowance for the auxiliary production process (t-CO₂).

2.3.1 Method for the Handling Production

The handling production include four processes: shore-side operation, horizontal transportation, storage area operation and truck-side operation^[5] for which the initial allowance are all calculated with the baseline method. The reference value of the carbon emission intensity at each process can be determined with the following two ways.

(1) The carbon emission intensity sequence method

The reference value is determined by sequencing the carbon emission intensity of a handling production process of main port enterprises in the region, with the computational formula shown in Equation (4).

$$EU = \sum_{i=1}^4 C_{i,x\%} \times T \quad (4)$$

Where,

EU - the allowance for the handling production process (t-CO₂).

$C_{i,x\%}$ - the x^{th} value at sequence C_i in order of carbon emission intensity of main port companies' handling production process i (t-CO₂/10⁴t or t-CO₂/10⁴TEU).

T - the throughput (t or TEU).

(2) Standard estimation method

The carbon emission reference value of each production process is directly given in accordance with relevant industrial standards, with the computational formula shown in Equation (5).

$$EU = \sum_{i=1}^n \sum_{j=1}^m q_{ij} \times \omega \times \eta \times \mu \times T \quad (5)$$

Where,

EU - the allowance for the handling production process (t-CO₂).

q_{ij} - the energy consumption intensity of the j^{th} kind of equipment used in the i^{th} handling production process, and the unit will be determined in accordance with the detailed provisions of the selected standard, generally including kWh/t, kg/t, kWh/t·m etc.

ω - the conversion coefficient of equipment operational quantity. It is a coefficient for the conversion between the unit operational quantity intensity of each main energy consumption equipment and the throughput, and its unit varies with the unit of the energy consumption intensity.

η - the emission reduction coefficient (%). It is the ratio between the determined value of energy consumption by a handling equipment and the value of energy consumption specified in the standard which is determined by the competent authority itself for the purpose of encouraging companies to take actions to reduce carbon emissions

μ - the fuel carbon emission factor. It is the carbon emission quantity per unit energy consumption quantity of each kind of fuel, with the unit related to the kind of the fuel.

T - the throughput (t).

2.3.2 Method for the Auxiliary Productions

The auxiliary production processes generally include vehicles and ships operating in port, machine repair and maintenance, production office buildings, water supply and drainage, environmental protection facilities etc^[6]. For all kinds of terminals, the initial allowance for each auxiliary production process is allocated with the historical intensity method, with the computational formula shown in Equation (6). Especially, though the site lighting and passenger transport service are usually included in the handling production processes, they are included in the auxiliary production processes in this study considering their energy consumption quantity are closely tied to some objective conditions, such as the

area of the storage yard and the passenger hall and the historical intensity method is fitter for them.

$$EA = \sum_{i=1}^3 (Ch_i \times \frac{T_j}{\sum_{i=1}^3 T_j}) \quad (6)$$

Where,

EA - the allowance for the auxiliary production process (t-CO₂).

Ch_i - the carbon emission intensity of the auxiliary production in the i years before the calculative period (t-CO₂/10⁴t or t-CO₂/10⁴TEU).

T_j - The annual throughput in the j years before the calculative period(t).

3 Method Applications

3.1 Scenario Description

It is assumed that 9 port companies are eligible and will join the carbon emission trading market in region A, including 3 specialized container terminals, 4 specialized dry bulk cargo terminals and 2 universal terminals. On the basis of the energy statistic data of main port companies in region A, the mixed allocation method is used to do the initial allocation in the given scenario.

3.2 Allowance Calculation

It is relatively simple to use carbon emission intensity sequence method and the historical intensity method, and the details will not be given. The process to use the standard estimation method is described as below:

1) Identify the reference handling procedure and main energy consumption equipment at terminals for different kinds of cargoes. In this case, main energy consumption equipment in each production process will be selected from conventional equipment in conventional handling procedure, and equipment operational coefficients will be set by fully considering the actual production conditions of main port companies in the region.

2) Select appropriate threshold or level standard on energy consumption of handling equipment and set the emission reduction coefficient to get the energy consumption intensity for main energy consumption equipment. Since no unified energy consumption threshold standard is established for the operational processes in port production in China, in this case, the energy consumption intensity will be generally referred to JTS 150-2007 Specification for Energy Conservation Design of Port and Waterway Engineering^[7]. Taking into account that Specification for Energy Conservation Design of Port and Waterway Engineering was set in earlier years, in which the unit energy consumption threshold for equipment may be high; in this case, the emission reduction coefficient is uniformly taken as 90%.

3) In accordance with the selected standard, the reference values of relevant parameters in the region are set one by one, for instance, the plane layout parameters,

the equipment operational coefficient and the production proportional coefficient. Finally, the conversion coefficient of equipment operational quantity is determined.

4) Calculate the carbon emission reference value for each production process with defined formulas.

3.2.1 Specialized container terminals

Main energy consumption equipment in each production process are identified based on the conventional process for handling productions at specialized container terminals, and the conversion coefficient of operational quantity is given for each equipment, as shown in Table 2. Here, the terminal loading/unloading ship proportion is set as 1:1, and the direct loading and direct delivery proportion is 10%.

Table 2. Main energy consumption equipment in handling production processes at specialized container terminals

Handling production process	Main energy consumption equipment	Conversion coefficient of equipment operational quantity
Shore-side handling	Quayside container crane	1.0
Horizontal transport	Container traction semitrailer	0.9
Storage area operation	E-RTG	2.6
	Empty container stacker	0.5
	Container reach stacker	0.2
	Loaded container forklift	0.3
	Empty container forklift	0.1

Based on Equation (5), the formula to compute the initial allowance for handling production at the specialized container terminals is:

$$EU_c = 54.5004 \times T \quad (7)$$

Where,

EU_c - the allowance for the handling production process at the specialized container terminal (t-CO₂).

T - the annual throughput (10⁴TEU).

3.2.2 Specialized dry bulk cargo terminals

Main energy consumption equipment^[8] in each production process are identified based on the conventional process for handling productions at specialized dry bulk cargo terminals, and the conversion coefficient of operational quantity is given for each equipment, as shown in Table 3. Here, the terminal loading/unloading ship proportion is set as 1:1, the direct loading and direct delivery proportion is 0 and the hold cleaning operational quantity is 10 % of the ship unloading operational quantity. In calculation, the length is set as 1000 m for the belt conveyor in the ship loading/unloading process and 500 m for the belt conveyor in the truck handling process.

Table 3. Main energy consumption equipment in handling production processes at specialized dry bulk cargo terminals

Handling production process	Main energy consumption equipment	Conversion coefficient of equipment operational quantity.
Shore-side handling	Mobile ship loader	0.5
	Bridge grab ship unloader	0.5
	Trimming bulldozer (for hold cleaning)	0.05
Horizontal transport	Belt conveyor	1.0
Storage area operation	Bucket-wheel stacker reclaimer	2.0
Truck handling operation	Truck loader	0.5
	Screw unloader	0.5

Based on Equation (5), the formula to compute the initial allowance for handling production at the specialized dry bulk cargo terminals is:

$$EU_b = 8.8598 \times T \quad (8)$$

Where,

EU_b - the allowance for the handling production process at the specialized dry bulk cargo terminal (t-CO₂).

T - the corporate annual throughput (10⁴t).

3.2.3 Universal terminals

The universal terminals include the universal bulk cargo terminals and the universal general cargo terminal. Their main energy consumption equipment in each production process are identified based on the conventional process for handling productions at specialized dry bulk cargo terminals, and the conversion coefficient of operational quantity is given for each equipment, as shown in Tables 4 and 5. Here, the terminal loading/unloading ship proportion is set as 1:1, the direct loading and direct delivery proportion is 50 % and the hold cleaning operational quantity is 10 % of the ship unloading operational quantity.

Table 4. Main energy consumption equipment in handling production processes at universal bulk cargo terminals

Handling production step	Main energy consumption equipment	Conversion coefficient of equipment operational quantity.
Shore-side handling	10t/16t gantry crane	0.5
	25t/40t gantry crane	0.5
	Single-bucket loader (for hold cleaning)	0.05
Horizontal transport	Traction trailer	1.0
Storage area operation	Single-bucket loader	1.0

Table 5. Main energy consumption equipment in handling production processes at universal general cargo terminals

Handling production process	Main energy consumption equipment	Conversion coefficient of equipment operational quantity.
Shore-side handling	10t/16t gantry crane	0.5
	25t/40t gantry crane	0.5
Horizontal transport	Dump truck	1.0
Storage area operation	Rubber-tired crane	0.7
	Forklift	0.3

The initial allowance for handling productions at the universal bulk cargo terminals and the universal general cargo terminals can be calculated with Equation (9) and (10) respectively.

$$EU_{gb} = 6.4651 \times T \quad (9)$$

Where,

EU_{gb} - the allowance for the handling production process at the universal bulk cargo terminal (t-CO₂).

T - the corporate annual throughput (10⁴t).

$$EU_g = 7.7327 \times T \quad (10)$$

Where,

EU_g - the allowance for the handling production process at the universal general cargo terminal (t-CO₂).

T - the corporate annual throughput (10⁴t).

3.3 Result Analysis

The carbon emission intensity sequencing (here, x is 50) and the standard estimation method are respectively used to calculate the carbon emission initial allowance for the handling production processes of the 9 companies, while the historical intensity method is used to calculate the carbon emission initial allowance for their auxiliary production. To verify the results from the mixed allocation method, the results calculated with the historical intensity method will be used as control, as shown in Table 6. The difference ratio in initial allowance between these 3 methods (the ratio between the difference value of the results of Methods 1 and 2 and the bigger value of them) are shown in Figs.1 ~ 3 respectively.

Table 6. Results calculated

company	The carbon emission intensity	Standard estimation method	Historical intensity method
c.Co1	107223.34	60569.06	102420.15
c.Co2	10295.89	6154.68	11532.82
c.Co3	20351.50	11373.09	9157.55
b.Co1	17913.85	18399.77	14927.53
b.Co2	1411.98	1448.71	1088.48
b.Co3	2384.61	2450.65	1069.79
b.Co4	834.51	855.12	866.67

g.Co1	5417.78	6172.14	5233.80
g.Co2	7640.57	10419.28	3531.32

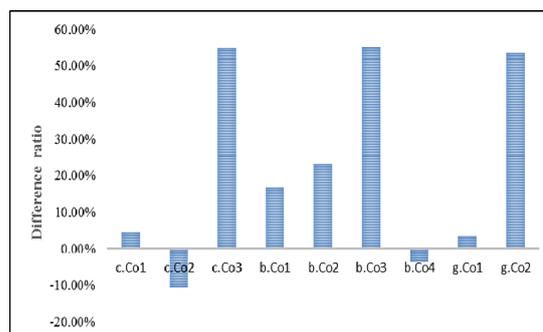


Fig. 1. The difference ratio of results from the carbon emission intensity sequencing and the historical intensity method

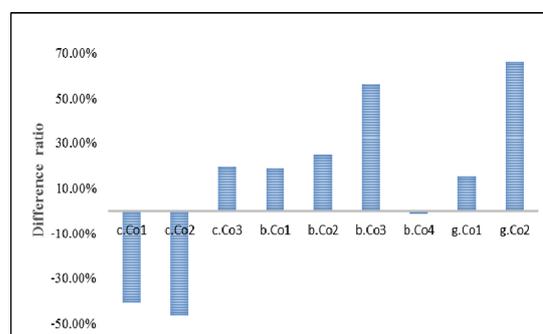


Fig. 2. The difference ratio of results from the standard estimation method and the historical intensity method

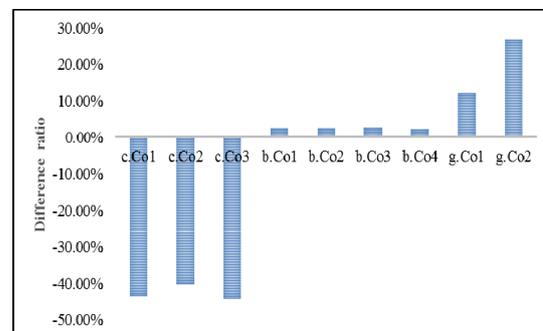


Fig. 3. The difference ratio of results from the carbon emission intensity sequencing method and the standard estimation method

These calculated results are analyzed that:

(1) With different allocation methods, the carbon emission initial allowance available to companies varies, and so does the allocation method the most favorable to them. On these 9 companies, the largest difference ratio of the basic allowance obtained with 3 methods is 66.11%. The mixed allocation method is more favorable to companies with better energy structure and high level of energy efficiency; on the contrary, the historical intensity method is more favorable to those with poor energy structure and low level of energy efficiency.

(2) The allowance difference obtained from these 3 methods varies significantly. The difference between results allocated with the standard estimation method and the historical intensity method is the largest, with the mean difference ratio of 32.19%. Among them, the

container terminals enjoy the highest difference ratio, possibly because: 1) in the standard estimation method, the set value of the operational coefficients of such handling equipment as E-RTG, empty container stacker, reach stacker and forklift is lower, and shall be adjusted based on the actual production in the region; 2) the handling production process of the container terminals in the region is relatively backward, so the energy consumption level of the handling equipment falls greatly behind the requirements in the standard.

(3) There are pros and cons in the carbon emission intensity sequencing and the standard estimation method. The carbon emission intensity sequencing requires port companies to provide detailed energy statistic data by steps and by energy-consumption types, which involves high basic statistic requirements and complicate computation. However, the reference values obtained are more accurate, more matching the actual conditions of emission-controlling companies. For the standard estimation method, the calculation is pretty complicate in the initial use, and once the value of all coefficients is determined, it is easy for later use. However, since the method requires the industry to establish rational standards on energy consumption thresholds or level of handling equipment, currently the estimation is rough and the results are low in accuracy. In the actual operation, it is required to adjust various parameters involved in the method, to obtain the computational formula for the allocation methods that are scientific, fair and meet the need of the competent industrial authorities. The acknowledgements should be typed in 9-point Times, without title.

4 Conclusion

This paper proposes a mixed allocation method for the initial carbon emission quota in the port industry. This method takes into account the fact that the loading and unloading production processes of port enterprises are relatively consistent, but the auxiliary production processes are quite different, so that the initial allowance is calculated with the baseline method for the handling production and with the historical intensity method for the auxiliary production. Relative to single use of the historical intensity method or the baseline method, the mixed allocation method, although complex in operation, is fairer and more reasonable because it not only considers the historical emission basis of emission-controlling companies, but also plays a certain role in promoting companies' emission reduction by setting the reference intensity for the handling production processes. Overall, the mixed allocation method proposed in this paper is a scientific, fair and feasible carbon emission allowance allocation method that better matches the characteristics of China's port industry energy consumption statistics at present.

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