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Comparison of Carbon Emission Trading Schemes in the European Union and China

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Received: 2 August 2017; Accepted: 30 August 2017; Published: 2 September 2017

Abstract: Given the growing evidence and scientific consensus on global climate change, carbon emission trading schemes (ETS) have been deemed crucial in mitigating the problem. Therefore, this study compares the mechanisms of ETS in the European Union with those in China. The results indicate similarities in cap determination, the coverage and calculation method of allowance allocation, trading participants and allowance category, offset credit, and MRV. On the other hand, the allocation method and supervision of allowance allocation, allowance formats and trading methods, market risk management, market linkage mechanism, and legislation security evidently appear to vary. However, the results were unable to identify which ETS is absolutely good or bad due to the political, economic, and institutional contexts and the varying developmental phases. Eventually, drawing on these findings, we conclude with implications for the promotion of ETS.

Keywords: carbon emission trading scheme; comparative study; European Union; China

1. Introduction

Carbon emission trading schemes (ETS) aim at realizing emission reduction targets proposed in the 1997 Kyoto Protocol [1–4]. ETS were also proposed to counter climate issues raised during the 2015 Paris Climate Summit and 2016 Marrakech Climate Summit. Countries or enterprises use ETS as a platform to sell redundant allowances or buy deficient ones to fulfill their carbon reduction duty. According to the polluter-pays principle, under an ETS, emitters must incur external costs that negatively affect others [5]. Numerous countries and regions have employed ETS to mitigate climate change, including the European Union (European Union Emission Trading Scheme [EU ETS]), the United States (Regional Greenhouse Gas Initiative [RGGI]), China, Korea, and Japan. A complete ETS comprises mechanisms such as cap determination and market trading [6–8]. However, owing to the lack of experience [8,9] and macro-economic environment changes [10], the carbon market faced low carbon prices, allowance oversupply, and low marketization. For instance, the 2008 finance crisis created a sluggish economy and thus, surplus allowance in the EU ETS. In other words, the ETS was deemed unsuccessful and a measure that yields satisfactory results, but only in the short run. Thus, it is imperative to improve such schemes step by step and learn from the experiences of other countries and regions that have implemented ETS. At present, the EU ETS is the largest carbon emission trading scheme in the world. China's carbon trading market is expected to be the second largest once it establishes a national ETS in 2017. China has also attempted to implement seven pilot ETS. Therefore, it is meaningful to compare the mechanisms of ETS between the European Union (EU) and China.

Numerous studies have explored ETS given that they are considered the most efficient measure to mitigate climate change [11]. For example, many researchers have analyzed the EU ETS using designed mechanisms [12]; operational conditions [13,14]; allowance allocation [15,16]; monitoring, reporting, and verification (MRV) [17]; carbon price [18–20]; carbon finance [21]; and international

cooperation [22]. Some scholars have explored the effects of the EU ETS [23–25]. On the other hand, the literature provides an overview of China's ETS [1,3,26], particularly allowance allocation [27,28], MRV [29], carbon price [30], and carbon credit [31] in the context of China's pilot ETS. Studies have also been conducted on the effects of China's ETS on emission reduction [32]. Moreover, research exists on RGGI [33], New Zealand ETS (NZ ETS) [34,35], and ETS in Japan [36] and Korea [37]. However, of the eight mechanisms composing ETS, scholars tend to focus on select ones. For example, Liu and Wang compared MRV between the EU and Japan ETS and offer several implications for China's pilot schemes [29,38]. Xiong, Shen, and Qi analyzed the allowance allocation in the EU, California, and China [39]. Dong, Ma, and Sun explored compliance entities, allocation methods, transaction participants, and trading methods for the EU ETS, RGGI, and NZ ETS [8]. Tanaka compared methods to assess CO_2 emission reductions between the EU ETS and Japan ETS [40], and Kockar compared the market clearing price in the electricity market between the EU ETS and RGGI to determine similarities and differences [41].

The above literature review reveals that most previous studies focus on ETS in one country, while comparative analyses remain limited. There is also a striking gap in comparative studies between the EU ETS and China's pilot ETS, a gap in the literature that this study attempts to fill.

The remainder of this paper is organized as follows. Section 2 describes the methodology adopted in the study, particularly the regions of interest and indicator designs. Section 3 presents the results and discussion. Section 4 focuses on implications for ETS establishment. Section 5 concludes.

2. Methodology

2.1. Study Locations

We focus on ETS in the EU and China because they are the first and second largest carbon emission trading markets in the world. At the 1997 Kyoto Protocol, the EU committed to reducing greenhouse gas (GHG) emissions by 8% during 2008–2012 compared to the rate reported in 1990 [42], and in 2005, established ETS to achieve this target. A total of 25 EU member states participated in Phase 1 (2005–2007) of the scheme. In 2008 (Phase 2), Iceland, Liechtenstein, and Norway joined the scheme. Phase 3 of the EU ETS, that is, from 2013 to the end of 2020, aims at reducing emission levels by about 21% below the 2005 level [43]. In fact, from 2008 to 2012, the EU reduced 462 million ton CO_2 equivalent (Mt CO_2e), thus fulfilling the promise it made at the 1997 Kyoto Protocol. Moreover, in 2015, the total emission was 23.6% below the 1990 level [44].

In 2005, the net GHG emissions in China increased to 70.46 billion CO_2 equivalent (CO_2e) [45]. In 2009, China became the highest emitter and its carbon emission level is expected to continue increasing till 2030 [46]. However, at the 2009 Copenhagen Climate Summit, the Chinese government committed to decreasing its carbon intensity by 40–45% compared to the 2005 level by 2020. To achieve this target, China adopted numerous programs, including the ETS pilot program. During 2014–2016, China's pilot ETS program, including two provinces and five municipalities (Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Guangdong, and Hubei), was in its preliminary phase, which is expected to eventually lead to a national ETS. The pilot areas span across the north, mid-west, and southeast coastal areas of China (Table 1). The regions vary in economic development, indicating unbalanced conditions among China's provinces. The overall population, gross domestic product (GDP), and energy consumption in the pilots, respectively, accounted for 19%, 27%, and 24% of the national total [47].

Table 1. General characteristics of pilot regions.

Region	Population (Thousand)	GDP (Billion Yuan)	Energy Consumption (Million Ton Coal Equivalent)	Energy Consumption per GDP (Ton/Ten 1000 Yuan)	Geographic Location
Beijing	19,610	1411.36	69.54	0.49	North
Tianjin	12,940	922.45	68.18	0.83	North
Shanghai	23,040	1716.60	111.61	0.71	East
Chongqing	28,850	792.56	71.17	1.13	Mid-west
Shenzhen	10,372	958.51	49.15	0.51	Southeast
Guangdong	104,300	4601.3	271.95	0.66	Southeast
Hubei	57,240	1596.76	151.38	1.18	Mid-west

Source: China Statistical Yearbook (2011), Province and Municipality Statistical Yearbook (2011) [48–54].

2.2. Comparative Indicators Design

According to international ETS practices [6–8], a complete ETS comprises the following mechanisms: cap determination, allowance allocation, MRV, market trading, offset credit, market risk, market linkage, and legislation security. For the purpose of this study, we adopt the eight mechanisms as comparative indicators and drawing on the existing literature, design 19 sub-indicators (see Table 2). We compare cap determination using target, determination method, and allowance category. We study allowance allocation using coverage, allocation method, and calculation method. Here, we also include supervision of allocation considering the need for a fair distribution process. Market trading comprises participants, trading allowance category, transaction method, allowance format, and carbon price; however, we exclude carbon price because China's pilot ETS are in a nascent stage and do not set a stable carbon price. Given the limited studies on carbon offset projects, we examine offset credit using three sub-indicators: offset ratio, restricted areas, and date. We compare market risk management using non-compliance punishment, as in Dong's study [8]. Finally, given the oversupply that emerged in the EU ETS and China's pilot ETS, measures to control cap warrant research. Thus, we conduct an in-depth analysis of MRV, market linkage, and legislation security.

Table 2. Comparative indicators and sub-indicators.

Indicators	Sub-Indicators	References
Cap determination	Target Determination method Allowance category	Jing, De, and Bin [1]; Duan, Pang, and Zhang [6]; Jotzo and Loschel [55]
Allowance allocation	Coverage Allocation method Calculation method Supervision	Duan, Pang, and Zhang [6]; Vlachou [7]
Market trading	Participants Trading allowance category Trading method Allowance format	Jing, De, and Bin [1]; Bailey [14]
Offset credit	Offset ratio Restricted areas Date	Zhang [26]; Lo and Cong [31]; Zhang, Karplus, and Cassisa [56]
Market risk management	Cap control measure Non-compliance Punishment	Duan, Pang, and Zhang [6]; Zhang, Karplus, and Cassisa [56]
Monitoring, reporting and verification		Liu, Chen, and Zhao [3]; Wartmann and Groenenberg [17]
Market linkage		Jing, De, and Bin [1]; Jepma [22]
Legislation security		Duan, Pang, and Zhang [6]

3. Results and Discussion

3.1. Similarities

3.1.1. Setting of Reduction Target to Determine Cap

During the first and second compliance periods of the EU ETS, emissions were reduced by 8% in 2012 compared to the 1990 level [42]. In Phase 3, the EU ETS aims to further reduce emissions by about 21% below the 2005 level. At the same time, against the background of the 2020 Climate and Energy Package Plan [57], the EU ETS intends to reduce GHG emission levels by 20% compared to the 1990 level, ensure that renewable energy accounts for 20% of energy consumption, and increase energy use efficiency by 20% by 2020. China employed a similar strategy. It set a reduction target in its seven pilot ETS on the basis of the l2th Five-Year Plan, which aimed to decrease CO_2 emissions per GDP by 17% and energy consumption per GDP by 16% in 2015 compared to the 2010 values. Table 3 presents the final reduction targets according to regional reduction targets, economic structures, and industry characteristics.

Table 3. Reduction target of China's pilot ETS.

Pilot ETS	CO_2 Emission per GDP (%)	Energy Consumption per GDP (%)
Beijing	18	17
Tianjin	19	18
Shanghai	19	18
Chongqing	17	16
Shenzhen	21	19.5
Guangdong	19.5	18
Hubei	17	16

Source: Work Plan for Greenhouse Gas Emission Control during the 12th Five-Year Plan Period, Guangdong Province, China [58,59].

3.1.2. Use of Up-Bottom Method to Decide Cap

In Phases 1 and 2, the cap for the EU ETS was decided using the bottom-up method. National allocation plans (NAPS) designed by each country determined the allowance allocation for each compliance period. It is necessary that such plans are in accord with the emission duty stipulated in the 1997 Kyoto Protocol. In other words, the sum of NAPS is treated as the cap in the EU ETS. Contrary to the former two phases, the setting of an EU-wide cap was proposed only recently. Using this method, this cap annually decreased by 1.74% as per the average annual allowance quantity in 2008–2012 [43].

China, excluding Chongqing, also adopted the up-bottom method to determine a cap for ETS. The process includes three steps. First, each pilot decides the reduction target on the basis of the national reduction goals and regional economic growth target. Second, a base year is selected and an emission ratio is calculated for compliance entities. Finally, the cap is decided for the province or municipality. As for Chongqing, the employed method was the same as that in phases 1 and 2 of the EU ETS: the entities determined the allowance quantity and reported it to the local carbon management department.

3.1.3. Reservation of New Entrant Allowance in Cap

Considering the possibility of an enlarged coverage, new entrant allowance (adjusted allowance in Shanghai) was reserved and this helped develop new facilities and installments in the EU ETS and China's pilot ETS (except in Chongqing) (see Table 4). Moreover, in China, most allowances were freely allocated and the carbon price equilibrium was difficult to ascertain, which was related to the success or failure of an auction. Thus, the reserved allowance in Guangdong and Hubei also served as a means to determine carbon price.

Table 4. Allowance categories in EU ETS and China's pilot ETS.

Region	Allowance Categories
EU ETS	Initial allowance, New Entrant Reserve (NER)
Beijing	Existing installment allowance, new entrant allowance, adjusted allowance
Tianjin	Existing installment allowance (adjusted allowance and initial allowance), new entrant allowance
Shanghai	Entity allowance, adjusted allowance
Chongqing	Entity allowance
Shenzhen	Entity allowance, new entrant allowance, reserved allowance for adjusted and other allowances
Guangdong	Entity allowance, reserved allowance (new project and adjusted allowance)
Hubei	Existing installment allowance, new entrant allowance, government-reserved allowance

Source: Official website of European Commission and Annual Review of Low-Carbon Development in China (2014–2016) [60–62].

3.1.4. Inclusion of Energy-Intensive Industries

Energy-intensive industries consume a significant amount of fossil energy. Fossil fuel consumption annually accounts for more than 30 billion metric tons of global CO_2 emissions [63]. In the EU, about 40–45% of GHG emissions were attributed to CO_2 emissions from energy-intensive industries [64], which triggered their inclusion in the EU ETS, as well as China's pilot ETS. Other industries with lower GHG emissions are partly included and this step will be gradually expanded in the EU ETS (Table 5).

Table 5. Industries included in EU ETS and China's pilot ETS.

Region	Industries
EU ETS	Phase 1: CO_2 from power and heat generation, cement, and 12 other industrial sectors Phase 2: Aviation and N_2O from nitric acid Phase 3: N_2O from nitric acid, adipic acid, glyoxylic acids and glyoxal, PFCs from aluminum production
Beijing	Heat and power generation, petrifaction, cement, service industry $\geq$10,000 ton CO_2 (2013, 2014); mobile sources and capital equipment $\geq$5000 ton CO_2 (2015)
Tianjin	Power and heat generation, chemical, petrifaction, and four other industrial sectors $\geq$20,000 ton CO_2
Shanghai	Power generation petrifaction, chemical, and seven other industrial sectors $\geq$20,000 ton CO_2 in 2011 or 2012; aviation and seven other service industries $\geq$10,000 ton CO_2 in 2011 or 2012
Chongqing	Iron and steel, cement, and four other industries $\geq$20,000 ton GHG (CO_2, CH_4, N_2O, PFCs, FHCs, SF_6) in any year from 2008 to 2012
Shenzhen	Industrial sectors, public institution, and large-scale public building $\geq$3000 ton CO_2; state-owned office building $\geq$10,000 square
Guangdong	Power generation, iron and steel, petrifaction, cement $\geq$20,000 ton CO_2 or 10,000 ton coal equivalent 2011 or 2012
Hubei	Power generation, cement, chemical, and 12 other industrial sectors $\geq$60,000 ton coal equivalent

Source: Official website of European Commission and NRDC and Annual Review of Low-Carbon Development in China (2014–2016) [60–62].

3.1.5. Combining Grandfathering and Benchmarking to Calculate Allocated Allowance

Grandfathering and Benchmarking are key methods used to calculate allowances in most ETS. Allocated allowances can be estimated using extant data and by employing the Grandfathering technique. Therefore, accurately recorded emission data are important. However, Benchmarking is related to the maximum level of energy conservation or emission reduction in an industry and compliance entities in the industry are expected to achieve this standard. However, Grandfathering does not effectively promote energy efficiency and it is impossible for all industries to reach the maximal level under Benchmarking. Therefore, both techniques are combined to calculate the allocated allowance (Table 6).

Table 6. Methods of allocating allowance in EU ETS and China's pilot ETSs.

Region	Calculation Allowance Method
EU ETS	Phase 1 and 2: Grandfathering Phase 3: Benchmarking (manufacturing industry); Grandfathering (other industries)
Beijing	Benchmarking: new installment; Grandfathering: existing installment
Tianjin	Benchmarking: power and heat generation; Grandfathering: other industries
Shanghai	Benchmarking: service industry, power generation; Grandfathering: energy-intensive industries
Chongqing	Competition and game method with government control on cap allowance
Shenzhen	Competition and game method: manufacturing industry; Grandfathering: construction industry
Guangdong	Benchmarking: cement, power generation; Grandfathering: steel works and production of iron, petrifaction
Hubei	Benchmarking and Grandfathering: power generation; Grandfathering: other industries

Source: Official website of European Commission and Annual Review of Low-Carbon Development in China (2014–2016) [60–62].

3.1.6. Development of MRV

The MRV mechanism, which involves monitoring, reporting, and verification, provides an ETS with emission data. Both the EU ETS and China's pilot ETS require compliance entities to develop in advance a monitoring plan that includes emission sources, monitoring methods, and frequencies in specific sources. However, the monitoring plan in Chongqing and Shenzhen is not mandatory, although they are required to submit an annual report, including the total emission quantity, fuel consumption, monitoring measures, and mitigation actions, for all schemes. Shenzhen is required to submit seasonal emission reports. An independent institute is employed to verify the accuracy and reliability of relevant data in the report. The carbon emission management department in each state of the EU ETS is responsible for the monitoring and reporting and an authorized department evaluates the quality of verification institutions. The local Development and Research Commission (DRC) is responsible for the MRV mechanism for China's pilot ETS.

3.1.7. Trading Participants and Allowance Categories

Transaction activities under the EU ETS and China's pilot ETS are organized and supervised using a unified trading platform (Table 7), which plays a significant role in issuing trading information. Trading participants are not limited to the compliance entities; even enterprises and organizations with no emission reduction responsibility are permitted to participate in transaction activities to promote market competition. The unified trading platform is also open to the trade of offset credit and initial allowance. Offset credit is traded to decrease compliance entities' costs. In addition, it can broaden affected sources to reduce emissions [65]. In the EU ETS, offset credit included Certified Emission Reductions (CERs) and Emissions Reductions Units (ERUs), which were produced by the Clean Development Mechanism (CDM) and Joint Implementation (JI) by international cooperations; however, in the case of the seven pilot ETS, offset credit emerged within China.

Table 7. Trading participants and allowance categories in EU ETS and China's pilot ETS.

Region	Platform	Participant	Allowance Category
EU ETS	European Energy Exchange (EEX), European Climate Exchange (ECX), Power-next Exchange, Nard Pool (NP), Bluenext Exchange, Climax Exchange	Compliance entities, other enterprises, and natural persons	Initial allowance, CERs, ERUs
Beijing	China Beijing Environment Exchange	Compliance entities and other enterprises	Initial allowance, CCERs
Tianjin	Tianjin Climate Exchange	Compliance entities, institutes enterprises, organizations, natural persons	Initial allowance, CCERs
Shanghai	Shanghai Environment and Energy Exchange	Compliance entities, other organizations	Initial allowance, CCERs
Chongqing	Chongqing Carbon Emission Trade Center	Compliance entities, other enterprises, organizations, and natural persons	Initial allowance
Shenzhen	China Shenzhen Emissions Exchange	Compliance entities, other institutes, natural persons	Initial allowance, CCERs
Guangdong	China Guangdong Emission Exchange	Compliance entities, new-project, organizations, natural persons	Initial allowance, CCERs
Hubei	Wuhan Optics Valley United Property Rights Exchange	Compliance entities and new-project developers	Initial allowance, CCERs

Source: Official website of European Commission and Annual Review of Low-Carbon Development in China (2014–2016) [60–62].

3.1.8. Limited Offset Credit Usage Ratio, Date, and Production Areas

Undoubtedly, offset credit considerably influences the linkage of other mitigation actions. In particular, international credit in the EU reduces compliant costs, which protects compliance entities' competitiveness, and helps developing countries bring low-energy devices to improve energy efficiency. However, the usage ratio, date, and production areas are restricted in the EU ETS and China's pilot ETS. From the development process of EU ETS, it is clear that constraint conditions are made more stringent as the scheme improves (Table 8). These constraints are initiated given the potential of offset credit to foster compliance entities' investments in low-cost mitigation actions in other countries or provinces to complete compliance duties prior to the deadline. Thus, at the same time, it discourages the implementation of local emission reduction activities.

Table 8. Carbon offset restriction conditions in EU ETS and China's pilot ETS.

Region	Usage Ratio	Date	Production Areas
EU ETS	Phase 1: no restriction Phases 2 and 3: quantity per participant determined by member states and approved by European Commission	CERs or ERUs issued in Phase 2 must be revised for allowances before 31 March 2015	Phase 3: new-project CERs from or swapped for CERs from least developed countries (LDCs) can offset
Beijing	≤5% initial allowance and >50% offset credit	After 1 January 2013	CCERs produced in Tianjin and Hebei
Tianjin	≤10% actual emission	After 1 January 2013	CCERs from Beijing, Tianjin, and Hebei has the priority
Shanghai	≤5% initial allowance	After 1 January 2013	N/A
Chongqing	≤8% actual emission	After 31 December 2010	N/A

Table 8. *Cont.*

Region	Usage Ratio	Date	Production Areas
Shenzhen	≤10% initial allowance	N/A	Provinces signed agreements with Shenzhen
Guangdong	≤10% actual emission and ≥50% offset credit	N/A	N/A
Hubei	≤10% actual emission	N/A	Provinces signed agreements with Hubei

Source: Official website of European Commission and NRDC and Annual Review of Low-Carbon Development in China (2014–2016) [60–62].

3.2. Dissimilarities

3.2.1. Allocation Methods and Supervision Systems

In the final phases of the EU ETS, the allowance allocation method underwent changes such that the percentage of free allowance declined from 100% in Phase 1 and further from the 90% in Phase 2 [66]. Contrary to the previous phases, Phase 3 employed the auction as the default method for allowance allocation. It is estimated that by the end of Phase 3, the proportion of auction would increase to 57% [67]. Most allowances in China's pilot ETS are freely allocated; however, similar to Phase 1 of the EU ETS, Hubei auctioned less than 30% of governmental allowance and Guangdong auctioned 3% of the entity and new project allowances.

In addition, the EU ETS has a better supervision system than that of China's pilot ETS. The system ensures justice, rationality, and transparency in the allowance allocation process. The European Commission and all its member states promote the system and have cooperated to appoint an auction monitor under a joint procurement agreement. The monitor is required to submit a monthly report on the auctions held in the month and an annual consolidated report on the functions of the auction platforms. In addition, the auction monitor can be requested to prepare ad hoc reports on suspected breaches.

3.2.2. Allowance Formats and Trading Methods

While spot products are traded on the carbon market of both the EU ETS and China's pilot ETS, carbon futures and options are only traded under the EU ETS. Despite several carbon finance products being explored in Beijing, Shanghai, Guangdong, Hubei, and Shenzhen, the pilot schemes are in a nascent stage and the carbon finance markets are under construction. Further, the trading methods differ between the EU ETS and China's pilot ETS. It appears that public bidding is the only designated method in the EU and negotiation transactions conducted in most of China's pilot ETS are not adopted in the EU ETS. Nevertheless, both aspects indicate a considerably higher marketization of the EU ETS than that of China's pilot ETS.

3.2.3. Risk Management

Cap control measures. The oversupply and low prices in the EU ETS' Phase 1 caused the cap in Phase 2 to decline by 6.5% compared to the 2005 level [66]. Further, the 2008 economic crisis and consequent depression contributed to the demand–supply imbalance in Phase 2. As a result, a linear factor of 1.74% is set to decrease the cap in each year of Phase 3 [43]. The European Commission also designed a Back-loading program to realize temporary balance by putting up allowances for auction. Under the program, the Commission reduced auction allowances for 2014, 2015, and 2016 to four, three, and two hundred million, respectively; however, it postponed the sale of these allowances and is expected to auction them at a value of three hundred million in 2019 and six hundred million in 2020 [68]. Another program assumed to resolve the structural imbalance by adjusting and controlling

allowance quantity in the market is the Market Stability Reserve (MSR). The program reserves a certain number of allowances in the event of an oversupply and releases allowances when a deficiency occurs. However, MSR is currently under assessment and will come into effect post-2020. Compared with the EU ETS, the cap control measure in China's pilot ETS is much simpler. Chongqing was the only municipality to annually decrease the cap by a linear factor of 4.13% during 2013–2015 to resolve the supply–demand imbalance [69] (Table 9).

Non-compliance punishment measures. To improve the compliance ratio and regularize compliance entities' environment behavior, the EU ETS imposed a penalty of €40 per ton in Phase 1 and €100 per ton in phases 2 and 3 on non-compliant entities [66]. China's pilot ETS, however, levies a fine only when entities fail to commit, in which case, the carbon management department asks these entities to complete this required action within a stipulated duration.

Table 9. Risk management measures in EU ETS and China's pilot ETS.

Region	Cap Control	No Compliance Punishment
EU ETS	Phase 2: cap reduced by 6.5% from 2005 level Phase 3: linear factor of 1.74% set to reduce in annual and Back-loading Post-2020: market stability reserve (MSR)	Phase 1: €40 penalty per ton Phases 2 and 3: €100 per ton
Beijing	N/A	Excessive emission amount deducted from initial allowance for the following year Penalty = 5 × market average clearing price × excessive emission amount
Tianjin	N/A	Disqualification of finance subsidies and government support
Shanghai	N/A	50–100 thousand CNY
Chongqing	Cap allowance annually decreased by a linear factor of 4.13% in 2013–2015	Disqualification of finance subsidies and government support
Shenzhen	N/A	Excessive emission deducted from initial allowance for following year Penalty = 3 × market average clearing price × excessive emission amount
Guangdong	N/A	Double of excessive emission deducted from initial allowance for the following year and fine of 50,000 CNY
Hubei	N/A	Double of excessive emission deducted from initial allowance for the following year and fine of <150,000 CNY

Source: Official website of European Commission and NRDC and Annual Review of Low-Carbon Development in China (2014–2016) [60–62]. Note: €1 = 7.8049 CNY.

3.2.4. Market Linkage Strategies

The market linkage strategy adopted by the EU is internationalization to initiate bilateral and multilateral cooperation with other countries and regions (Table 10). CDM combined the EU with developing countries and JI linked it with developed ones. The European Commission also founded the International Carbon Action Partnership (ICAP), in which countries with mandatory ETS gathered to offer experience and training courses to each other. Under these technical assistance projects by the EU, China and Korea, for example, have set up carbon emission trading schemes. The Commission also supports carbon market development through the Partnership for Market Readiness (PMR), a World Bank program targeted at assisting developing countries and emerging economies to prepare and implement ETS.

By contrast, the market linkage strategy in China's pilot ETS was internalization to combine domestic provinces with an aim to prepare national ETS (Table 10). In early 2013, Beijing signed

agreements with Tianjin, Hebei, Shanxi, and other provinces to develop cross-regional carbon trading. Hubei Province made considerable efforts to build its regional carbon market. In addition, various seminars on carbon market construction have been jointly held with other provinces and training activities conducted to improve carbon market efficiency. Although several pilots have been explored in the regional carbon markets in the past, a unified national-level market is yet to be achieved.

Table 10. Carbon emission trading cooperation in China's pilot ETS.

Cooperation Provinces	Conference or Agreement
Beijing, Tianjin, Hebei, Shanxi, Shandong, Inner Mongolia	Framework agreement to develop cross-regional carbon emission trading cooperation (2013)
Beijing, Tianjin, Hebei	Conference: The 6th Earth Temple Forum "The Jing-Jin-Ji Integration and National Carbon Market" (2015)
Beijing and Inner Mongolia	Agreement: Announcements of cross-regional carbon trading cooperation between Beijing and Inner Mongolia
Shenzhen and Baotou	Conference: Kick-off meeting for Baotou carbon emissions trading scheme construction (2015) Agreement: Strategy cooperation memorandum for carbon emission trading scheme construction
Shenzhen and Shanxi	Carbon trading training activities (2016)
Hubei	Conference: Green Development and National Carbon Market Construction (2014)
Hubei	Conference: China Carbon Market Innovation and Megalopolis Development Forum (2015)
Hubei, Shanxi, Henan, Anhui, Hunan, Jiangxi, Guangdong	Carbon trading cooperation agreements (2015) and training activities

3.2.5. Legislation Security

A well-functioning ETS is guaranteed by a complete and integrated legal system with fundamental legislation and specific laws. Under the EU ETS, the European Commission Directive functions as a fundamental legislator that guides carbon emission trading. Specific laws on registration, allowance allocation (i.e., auction and free allocation), MRV, trading, offset, market abuse, and anti-money are published to enhance enforcement and discipline. All laws are strictly formulated by the European Commission. With respect to China's pilot ETS, Interim Measures for the Administration of Carbon Emission Trading, a regulation published by NDRC in 2014, is a fundamental law directing carbon trading activities. In addition, following the national law, the seven pilots have formed management measures for temporary local carbon emission trading and specific laws (Appendix A, Table A1). The specific laws and regulations to the implemented at the national level remain a work in progress.

3.3. Discussion

This study is one of the first to compare ETS between the EU and China. We explored their similarities to draw insight on the internal discipline necessarily to establish effective ETS. The analysis revealed that the following ETS aspects are similar between both regions: cap determination, coverage and calculation method of allowance allocation, trading participants and allowance category of market trading, offset credit, and MRV (Table 11). These similarities are universal and essential rules that provide guidance on the process of establishing ETS.

In addition, we assessed differences between EU ETS and China's pilot ETS. It appears that the schemes between both regions differ in the distribution method and supervision of allowance allocation, trading method and allowance format for market trading, market risk management, market linkage, and legislation security (Table 11). This finding is supported by those of Dong, Ma, and Sun [8].

Considering the diverse national and local condition, the differences can be said to reasonably resolve special issues in each ETS.

The findings also revealed that the EU ETS is more systematized and effective than China's pilot ETS. First, China's pilot ETS emphasizes carbon trading activities to achieve the local reduction goal, and thus, carbon market development is independent and depends on the conditions of a province or municipality. However, the opposite holds true for the EU ETS. Second, in the case of national ETS in China, in 2017, the pilots' legislation systems were horizontally separated and the national legal system vertically imperfect owing to the lack of specific laws. Third, the EU ETS is managed by the European Commission, whereas China's pilot areas have more discretion in setting up ETS in accordance with NDRC instructions.

However, this comparative study was unable to identify which ETS is absolutely good or bad. This limitation can be attributed to the differing political, economic, and institutional contexts and the varying developmental phases between the EU ETS and China's pilot ETS. For instance, at present, even though the EU ETS is more effective than China's pilot ETS, De Perthuisand and Trotignon argued that the "EU ETS has been undermined variously by the weakness of its regulation, an undesirable overlap with other public policies and the far-reaching economic and financial crisis that caused the market price of allowances to plunge in the early phases" [10].

Table 11. Similarities and differences between EU ETS and China's pilot ETS.

Mechanism	Comparison Item	Similarities	Dissimilarities
Cap determination	Target	Y	
	Method	Y	
	Allowance category	Y	
Allowance allocation	Coverage	Y	
	Distribution method		Y
	Calculation method	Y	
	Supervision		Y
Market trading	Participants	Y	
	Trading allowance category	Y	
	Trading method		Y
	Allowance format		Y
Offset credit	Offset ratio	Y	
	Restricted areas	Y	
	Restricted date	Y	
Market risk management	Cap control		Y
	Punishment measures		Y
Monitoring, reporting, and verification		Y	
Market linkage			Y
Legislation security			Y

Note: Y = Yes.

4. Implications for ETS Establishment

4.1. Learn to Do but Not Imitate

This study clearly highlights the similarities and notable differences between the EU ETS and China's pilot ETS. The RGGI, California ETS, and other international ETS, which positively affect emission abatement, are also established on the basis of their political, economic, and institutional context. Thus, it is reasonable to say that imitation and blind copying can lead to a situation of non-acclimatization and thus, the failure of ETS and a considerable loss of manpower and resources. In other words, it is imperative to account for local conditions and learn from the experiences of

international ETS to establish a proper ETS. To this effect, unleashing "the top-level design and crossing the river by feeling the stone" spirit advocated by the Chinese government will contribute to the design and development of ETS.

4.2. Establish Unified Framework

An effective legislation framework is fundamental to the implementation of national ETS. The results of the comparative study revealed that China's temporary national laws offer general guidance and dispersive management and separate laws are obstacles in linking pilot regions. To establish cooperation among provinces and unified management in the national carbon market, it is imperative to improve and perfect legal systems by implementing separate national-level regulations for allowance allocation, MRV, trading, and penalties, as well as adding stipulations for provincial cooperation.

Moreover, it has been announced that the NDRC in China will allow provinces to develop local ETS, even in the case of national ETS [70]. This decentralized authoritarianism situation has empowered China's local government and DRC with greater discretion. In these contexts, the NDRC is also required to account for provincial differences.

4.3. Gradually Improve ETS

As mentioned, the success of the EU ETS and China's pilot ETS was not achieved through instance solutions, rather, several measures were taken to improve the scheme. First, auctions were introduced to allocate allowances to covered entities in line with the polluter-pay principle, and the auction ratio was increasingly adjusted. Second, Benchmarking substituted the Grandfathering technique in certain industries to calculate allowance; this is because the historical emission data used in Grandfathering was inadequate and Benchmarking aims at potential mitigation within an industry. Third, the coverage of carbon emission trading was expanded to include energy-intensive and service industries. In addition, to improve market liquidity, diverse participants were allowed to participate in the carbon market and carbon futures and options could be tentatively traded. Finally, additional measures were implemented to adjust allowance cap, punish non-compliant entities, and publish relevant laws on the basis of practical needs.

Furthermore, short-, mid-, and long-term targets are needed. These targets will help covered entities conduct reduction activities in an orderly manner and guide the evaluation of the real effects of ETS. The target for every phase is formulated by disintegrating regional and national long-term targets and should be adjusted according to international and national environmental policies.

4.4. Cooperate with International ETS

ETS is a policy instrument designed to respond to climate change, which impacts human activities and life. Cooperating with other countries and regions that have implemented ETS can help realize the flow of resources and optimize deployment such that it achieves Pareto efficiency [71]. In addition, it offers opportunities to exchange ETS-based theories and practice. In particular, China should refer to international experiences to gain insight on coordinating covered provinces to guarantee fairness and justice. Moreover, MRV, as well as carbon finance and risk management, in China's pilot ETS demonstrates scope for improvement.

5. Conclusions

The EU ETS and China's pilot ETS play a significant role in coping with climate issues. The research revealed similarities in cap determination, coverage and calculation method of allowance allocation, trading participants and allowance category of market trading, offset credit, and MRV between both schemes. In addition, it highlighted differences in the distribution method and supervision of allowance allocation, trading method and allowance format of market trading, market risk management, market linkage, and legislation security.

In sum, a generic template to implement ETS does not exist and regions or countries must develop ETS on the basis of local conditions. In comparison with the EU ETS, China's pilot ETS are less integrated in terms of preparing towards national ETS. Thus, policymakers should reference to international experiences with ETS, although they should be mindful of simply imitating them. In addition, a unified framework can guide and define rights and responsibilities for carbon trading. Accounting for problems such as oversupply in the EU ETS, ETS should be improved to maintain efficiency in line with actual needs. Finally, the government should facilitate broader international cooperation with the aim of mitigating climate change.

Acknowledgments: This research is financially supported by Unspanned Risks in China's Bond Market: Measurement, Pricing, Functional Mechanism and Portfolio Management of the National Natural Science Foundation of China [Grant No. 71501140] and A Research of Connecting Tianjin Pilot Carbon Emissions Trading with the National Carbon Market: Key Issues and Solutions [Grant No. TJZD17-028]. We also thank the editor and reviewers of Climate, whose comments have significantly improved this paper.

Author Contributions: Yong Liu and Yunpeng Su designed the research and revised the research; Mengya Zhang performed the investigation and wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Fundamental laws and specific regulations for EU ETS and China's pilot ETS.

Region	Fundamental Laws and Specific Regulations
EU ETS	**Fundamental law:** European Commission Directive Emission cap and allowance regulation: Commission decisions of 22 October 2010, and 9 July 2010 **Registration regulation:** Commission Regulation (EU) No. 389/2013 **Allowance allocation regulation:** Auctioning regulation: Commission Regulation (EU) No. 1031/2010 Free allocation: Commission Decisions of 27 April 2011, and 5 September 2013 **MRV regulation**: Monitoring and reporting regulation (MRR) and accreditation and verification regulation (AVR) **Carbon trading regulation:** Markets in Financial Instruments Directive (MiFID) and Regulation (MiFIR), European Securities and Markets Authority's Consultations on Financial Market Rules **Carbon offset regulation:** Commission Regulation (EU) No. 550/2011, Commission Regulation (EU) No. 1123/2013 **Punishment regulation:** Market Abuse Regulation (MAR) and Criminal Sanctions for Market Abuse Directive (CSMAD)
Beijing	**Fundamental law:** Interim administrative measures for carbon emissions trading in Beijing **Carbon trading regulation:** Circular on administrative measures for market operation of carbon emissions trading. **Carbon offset regulation:** Circular on administrative measures for carbon offsets of carbon emissions trading (trial). **Registration regulation:** Circular on registration of allowance account and opening carbon emission trading accounts in Beijing **MRV regulation:** Circular on submissions and verification of 2014 carbon emissions report and the associated work; Circular on the issuance of the first batch of accounting methods and reporting guidelines on greenhouse gas emissions for enterprises in the ten sectors (trial) **Punishment regulation:** Circular on specifying discretion of administrative punishments under carbon emissions trading
Tianjin	**Fundamental law:** Interim administrative measures for carbon emissions trading in Tianjin **Carbon offset regulation:** Circular on administrative measures for carbon offsets of carbon emissions trading in Tianjin **MRV:** Guidance on compiling report of carbon emissions in Tianjin, Guidance on verification of carbon emissions in Tianjin

Table A1. *Cont.*

Region	Fundamental Laws and Specific Regulations
Shanghai	**Fundamental law:** Trial administrative measures for carbon emissions in Shanghai **Allowance allocation regulation:** Circular on the allocation and management plan for carbon emissions allowances for 2013–2015 in Shanghai **MRV:** Circular on verification of carbon emissions in Shanghai (trial); Circular on accreditation and report of greenhouse gas emissions in Shanghai (trial) **Carbon offset regulation:** Circular on administrative measures for carbon offsets of carbon emissions trading in Shanghai **Registration regulation:** Circular on interim administrative measures for registration of carbon emissions allowance in Shanghai (trial)
Chongqing	**Fundamental law:** Circular on administrative measures for carbon emissions trading in Chongqing (trial). **Allowance allocation regulation:** Circular on administrative measures for carbon allowance in Chongqing (trial) **MRV regulation:** Guidance on reporting and verifying carbon emissions in industrial enterprises in Chongqing (trial) **Punishment regulation**: Circular on administrative measures for carbon emission trading risk in Chongqing (trial)
Shenzhen	**Fundamental law:** Interim administrative measures for carbon emissions trading in Shenzhen **Allowance allocation regulation:** Notice on auctioning under Shenzhen carbon emissions trading **Carbon offset regulation:** Circular on administrative measures for carbon offsets of carbon emissions trading in Shenzhen (trial). **MRV regulation:** Guidance on quantification and reporting of greenhouse gas emissions for organizations in Shenzhen; Guidance on verification of greenhouse gas emissions for organizations in Shenzhen **Punishment regulation**: Circular on administrative measures for carbon emission trading risk in Shenzhen (trial)
Guangdong	**Fundamental law:** Trial administrative measures for carbon emissions in Guangdong Province **Allowance allocation regulation:** Circular on initial carbon allowance allocation and work plan of Guangdong; Circular on administrative measures for carbon allowance in Guangdong (trial) **MRV regulation:** Circular on reporting and verifying carbon emissions for enterprises in Guangdong **Punishment regulation:** Circular on administrative measures for carbon emission trading risk in Guangdong
Hubei	**Fundamental law:** Trial administrative measures for carbon emissions in Hubei Province **Allowance allocation regulation:** Circular on initial carbon allowance allocation in Hubei Province **Carbon offset regulation:** Circular on administrative measures for carbon offsets of carbon emissions trading in Hubei Province **Registration regulation:** Circular on administrative measures for registration of carbon emissions trading in Hubei Province (trial) **MRV regulation:** Guidance on monitoring, quantification, and reporting of carbon emissions in industrial enterprises in Hubei Province; Guidance on verification of greenhouse gas emissions in Hubei Province (trial)

Source: Official website for Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Guangdong, and Hubei [72–78].

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