Guangdong's Carbon Trading System: A Review of Liquidity and Influencing Factors

Jingyan Fu, Menghao Wu and Junyan Liu

Abstract China's seven carbon-trading pilots were approved for establishment in 2011 and subsequently commenced operations starting June 2014. As the largest carbon market among the seven Chinese carbon-trading pilots, Guangdong is evaluated as the second-largest carbon market in the world, only being next to the European Union (EU). These pilots instigated enormous influence on the policy formulated towards the establishment of China's national unified carbon market in 2017 with implications for solutions to environmental and climate problems on a national and even global level. This paper mainly adopts a comparative analysis approach, first to compare the liquidity of the Guangdong carbon market nowadays with a prior period and then with the Hubei carbon market. It further compares the influencing factors of carbon market liquidity based on the former results. The analysis identifies the factors influencing the low liquidity of the Guangdong carbon market, including the separation between the primary and secondary markets, insufficient openness in the secondary market, lack of adequate investors, inadequate consideration of the distribution and collection of emission allowances, an irrational carbon finance product structure, as well as a backward trading mechanism. Finally, this paper offers suggestions and proposals based on the problems identified in the overall assessment.

Keywords Guangdong Province · Hubei Province · Carbon market · Liquidity · Comparative analysis · Influencing factor

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1 Introduction

To combat climate change, prior studies show that large-scale deployment of carbon capture and storage (CCS) is necessary to limit the increase in global average temperature to less than 2 °C by 2100 (Jorge H. García et al. 2018). Regarding the question of a carbon tax versus emissions trading, an ETS garners greater support than a carbon tax among stakeholders [1]. Many economists and policy-makers advocate price-based approaches, such as greenhouse gas emissions taxes and emissions trading programmes, or technology-based approaches, such as R&D subsidies and public–private R&D partnerships. The world generally seems to have become less (multi) polarized in terms of carbon emissions since 1992 [2]. Ultimately, however, both types of approaches rely on consumers and firms to make different choices [3].

Guangdong leads China's Provinces in industry, CO_2 emissions, and the size of its carbon-trading pilot. Understanding the driving forces of carbon emissions is necessary for policy formulation [4]. What changes will carbon emissions bring to China? The Regional Greenhouse Gas Initiative among the north-eastern states is expected to lead to an increase in the price of electricity in the region and beyond. In the RGGI region, the change depends on the portfolio of assets held by affected firms [5]. Industrial production and energy consumption have a significant positive impact on carbon emissions in both the short and long runs. Likewise, Granger causality analysis indicated a unidirectional causation from both industrial production and energy consumption to carbon emissions; e.g., the industrial and economic development in Bangladesh is taking place at the cost of environmental quality [6].

On December 19, 2013, Guangdong officially launched carbon emissions trading completing seven transactions on that first day; its total turnover is approximately 120 thousand tonnes and its average price is 60.167 yuan. During the first two years, Guangdong implemented a number of measurements to enliven the market, eventually occupying half of the nation. By July 27, 2015, the Guangdong carbon market's volume exceeded 20 million tonnes and the total turnover had reached 916 million yuan, accounting for 36.12% and 45.28%, respectively, of the entire nation's transactions. The Guangdong carbon market is generally good; it is not only at the vanguard of carbon trading and an important contributor to China's carbon market but also the third-largest carbon market in the world that is next to only the EU and Korea in terms of market scale.

However, the development of the Guangdong carbon market shows some worrying trends. From inception to the second commitment period, the liquidity of the market has demonstrated obvious deficiencies compared to those of Hubei, Shenzhen and the European Union. In the entire year of 2014, the Guangdong carbon market traded thousands tonnes of carbon allowance; the average price was 44.28 yuan per tonne, the highest price was 77 yuan per tonne and the lowest price was 21 yuan per tonne, showing great fluctuations in price. Compared with the Hubei market's annual volume of 7 million tonnes, the highest price of 26.59 yuan per tonne and the lowest price of 22 yuan per tonne, the Guangdong carbon market has the characteristics of smaller trade volume, dramatic price fluctuation and centralized transaction dates.

2 Literature Review

2.1 The Meanings of Carbon Market Liquidity

Because academics have not yet clearly defined liquidity in the carbon market, this paper will generally divide carbon market liquidity into four dimensions according to the above definition of liquidity:

The first dimension is breadth. Breadth is a concept that relates to price, generally exists in a carbon market with a market maker system and is often measured by quote spread. A small quote spread means the competition in the carbon market is more intense and the liquidity of the market is better. If there is no spread, the seller and buyer can reach a deal in accordance with their expectations, and the liquidity at this moment is the best. In one market with good breadth, the influence of transactions on the market is small.

The second dimension is depth. Depth is a concept relating to quantity and refers to the maximum volume traders can reach in a certain price. The greater the number is, the more depth the carbon market has, and the better liquidity. Gagelmann [7] asserts that if there are large amounts of transaction requests (orders) within a certain scope of the current price, then the carbon market has more depth. A carbon market with great depth means its liquidity is good, and vice versa; the same transaction may produce greater effects on the price in a low-depth market.

The third dimension is immediacy. Immediacy is a concept regarding time, referring to the time that a trader must wait to conduct a transaction. If an investor can deal more quickly at a certain price, then the liquidity of the carbon market is better. Prohibiting the intertemporal trading of emission allowances induce positive risk premium in futures prices when the trading of the contracts and their expiry take place in time periods separated by this trading ban [8].

The fourth dimension is resiliency. This means the speed at which prices return to the state of equilibrium after certain transactions cause fluctuations in price. If prices can return to equilibrium more quickly, the capacity of the carbon market to bear transactions is greater, its resiliency is higher, and its liquidity is better. In a highly flexible carbon market, it is difficult to produce unbalanced price.

2.2 General Influencing Factors of Carbon Market Liquidity

The Bank of International Settlements (BIS) noted in a report (1999) that the influencing factors of market liquidity can be divided into three categories: the design of the product, the market microstructure and the behaviour of the market participants. According to the BIS classification, this paper divides the influencing factors of the carbon market into three types:

Design of product

Designing a product that can match the diverse needs of different market participants is the first factor that should be taken into account. Only when we design a product to meet the needs of the majority can the enthusiasm of the market participants be increased, and as a result, the market liquidity may be improved.

Market microstructure

The microstructure of the market mainly includes the trading mechanism, market participants, transaction cost and transaction constraints. The trading mechanism is channelled for the sides to trade, and the common transaction mechanism includes the following three types. First, the buyer and the seller transact directly without any intermediate process. The second type is the market maker system, in which the sides must deal through the market maker, and the market maker quotes the respective price to each side. The third type is pairing and dealing automatically by a system, such as the call auction and the continuous auction.

Behaviour of market participants

Different characteristics of the participant will affect its decision-making and behaviours, such as its ability to bear risk, sensitivity to macroeconomic policies and expectations about the future market. When risk-averse investors increase, market liquidity may decrease. When the expectations of the future of all of the investors are the same, the market liquidity will also decrease. Therefore, the diversity of market participants is good for market liquidity. Additionally, laws, regulations and macroeconomic policy will influence the participants' behaviour.

2.3 Measurements of Carbon Market Liquidity

According to the theory of financial market microstructure, market liquidity is multidimensional. Fischer [9] proposed that the measurement of liquidity must factor in four conditions: depth, width, tightness and resilience. Although scholars have performed considerable research on how to measure market liquidity, there is still no consensus.

Current methods of measuring market liquidity focus mainly on four different perspectives: methods related to bid-ask spread, methods related to the influence of trading volume on price, methods combining price and volume and methods related to the time consumed waiting for trade. Among the above four, the methods related to bid-ask spread are mainly suitable for the quote-oriented market; it is not certain whether these methods suit the order-oriented market and the carbon market is not a market based on the market maker; as a result, these types of methods are not the most suitable for measuring carbon market liquidity. Additionally, the methods related to the influence of transaction on price include the market depth model of Kyle [10] and the simple transaction model; these methods often need great quantities of data on the

micro-market in the actual analysis, and the methods related to the time consumed waiting for trade are very much the same.

Because this paper must measure the daily liquidity of the carbon market, after considering the availability of data and the differences among the carbon markets, this paper opts for the methods combining the price and trade volume. Taking account of the suitability of each liquidity ratio, this paper ultimately uses a new method that combines the Martin index [11] and the Hui and Heubel liquidity ratio [12]; the formula is as follows:

$$\mathrm{MH} = \frac{|(P_t - P_{t-1})/P_{t-1}|}{V/Q_{\mathrm{ea}}} \tag{1}$$

In the formula, "MH" is the new liquidity index, "V" represents the trading volume of the carbon emission allowance on the exact trading day and "Q_{ea}" represents the amount of carbon allowance in circulation in the entire carbon market and is equal to the total amount of the designed allowance minus the allowance that has not been distributed. "V/Q_{ea}" represents the turnover rate of allowance. "P_t" represents the closing price on "t" trading day, and the numerator of the formula is the volatility of price on "t" trading day.

3 Liquidity Analysis of the Guangdong Carbon Market

3.1 Guangdong Carbon Market Liquidity

When there are no transactions or the price is completely stable, the MH index is not affected to reflect the fact of liquidity itself.[1] The trend of zero transactions, the liquidity with non-fluctuating price and the liquidity on a normal trading day are analyzed in the following.

3.1.1 The Trend of Zero Transactions

From December 19, 2013 to November 13, 2015, there were a total of 471 trading days (excluding holidays and temporary adjusted trading days); on 38.34% of those days, equal to 181 trading days, there were zero transactions. The monthly occurrence of zero transactions during this period is shown in Fig. 1.

The monthly frequency of zero transactions in the Guangdong carbon market showed a downward trend, and the market performance in the year 2014 was much better than that in 2013, especially the highest proportion, which was only 60% in 2014 and now reaches 100%. Second, the monthly proportion of zero transactions

[1] When there are no transactions, the MH index is invalid. When the price has no fluctuation, the MH index always remains at zero.

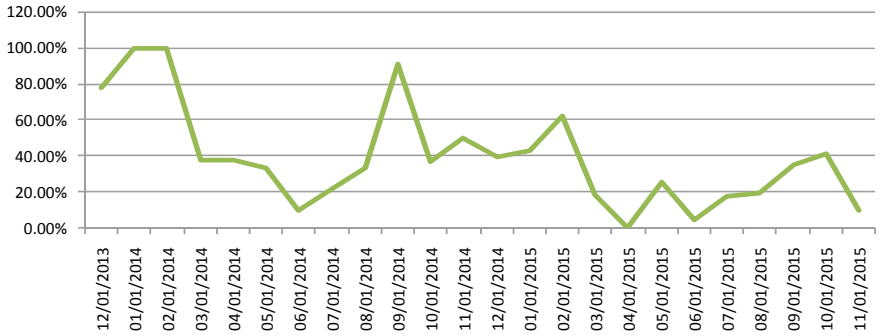

Fig. 1 Trend of monthly zero transactions from 2013/12/19 to 2015/11/13 in CEEX. *Source* http://www.cnemission.cn

in 2014 increased from 20 to 40% while it grew from 0 to 100% in 2013, indicating that the Guangdong carbon market was extremely unstable in 2013 and improved somewhat in 2014. Individually, there were obvious "V" cycle characteristics in both years. The proportion in June was the minimum of each year, and the market performance was the best.

3.1.2 The Liquidity with Non-fluctuating Price

There were a total of 23 days on which transaction did not affect the price from December 19, 2013 to November 13, 2015 (having ruled out situations where there were no transactions on a trading day), nine of which were in 2014 and the rest in 2015 (details are shown in Tables 1, 2).

Table 1 Dates and quantities of GDEA flowing into the market

Trading date	Trading volume (tonnes)	Trading date	Trading volume (tonnes)	Trading date	Trading volume (tonnes)
2014.03.11	5242	2014.11.13	2000	2015.07.28	1600
2014.03.18	100	2015.01.19	500	2015.08.14	25,000
2014.04.16	6	2015.01.22	1913	2015.08.17	26,833
2014.10.16	300	2015.01.26	1913	2015.10.21	1661
2014.10.30	1	2015.01.28	3	2015.10.22	58,539
2014.11.05	1000	2015.03.03	500	2015.10.23	20,500
2014.11.06	1000	2015.03.06	3000	2015.11.10	300
2014.11.07	1	2015.03.13	2000		

Source http://www.cnemission.cn

Table 2 Relevant regulations and policies of the Guangdong carbon market in 2015

Country level	"Overall plan for the reform of ecological civilization system"	September 21, 2015
	"USA-China Joint Presidential Statement on Climate Change"	September 25, 2015
	"France and China agree to monitor climate change pledges"	November 2, 2015
Province level	"The 2015 implementation plan of Guangdong carbon allowance"	August 18, 2015
	"The implementation plan of greenhouse gas emission report on key enterprises of Guangdong Province"	September 21, 2015
	"Notice on carrying out management of carbon emissions on reporting historical carbon emission information in Guangdong Province"	September 23, 2015
Exchange level	"Trading rules for carbon allowance"	August 31, 2015
	"Guidelines for carbon allowance repurchase business in Guangdong"	October 21, 2015
	"The process of registration and operation on carbon allowance mortgage business in Guangdong Province (for Trial Implementation)" "Detailed rules for controlling and managing carbon trading risk"	December 17, 2015

Source http://www.cnemission.cn

In terms of the trading dates shown in Table 2, the number of trading days without any price fluctuation continued increasing from 2014 to 2015. There were 7 such days during the first four months of compliance year 2015, which indicates the market was becoming increasingly stable. However, the liquidity still cannot be clearly determined under the circumstance of no price fluctuation on the trading day. Therefore, it is necessary to compare the trading volumes of the trading dates in Table 2; the trading volume trend of the 23 days is shown in Fig. 2.

Table 2 shows that the trading volume experienced a dramatic increase on August 14, 2015, and the overall trading in the following period was better than in the early stages. This shows that the trading volume's influence on price was gradually weakening and the ability of the Guangdong carbon market to bear risk had improved; the Guangdong carbon market was quietly changing.

3.1.3 The Liquidity on a Normal Trading Day

Further, we can directly use formula (1) to measure the liquidity of the Guangdong carbon market, and after eliminating several extreme values, which may disturb observation, this paper arrives at a figure to reflect the liquidity trend of a normal trading day on the Guangdong carbon market as shown in Fig. 2. We first see from Fig. 2 that there is a difference between the years 2014 and 2015; the MH index of

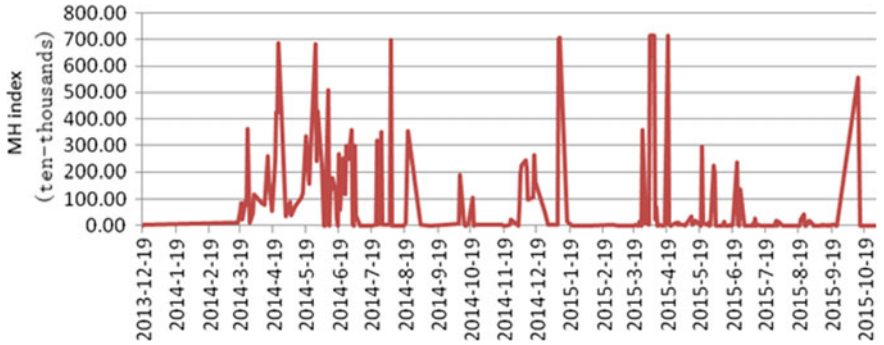

Fig. 2 Guangdong carbon market's MH index on a normal trading day. *Source:* http://www.cnemission.cn

the former was more centralized, and the majority of it basically remained above 100 million, while the MH index of the latter was scattered and had only a few high values, many of which were almost approaching zero.

3.2 Influencing Factors of the Liquidity of the Guangdong Carbon Market

Due to differences in liquidity in periods around compliance year 2015 in the Guangdong carbon market, to investigate why the liquidity changed and identify the factors that influenced this liquidity, this section will divide the development of the Guangdong carbon market into two periods: compliance year 2014 (from July 16, 2014 to June 23, 2015) and compliance year 2015. It will then compare the two stages from four aspects in accordance with the classification of the general influencing factors of the carbon market.

3.2.1 Laws, Regulations and Policies

Policies and regulations generally remain effective in the long term once promulgated; for instance, the National Development and Reform Commission of China published the "Interim Measures for the Management of Carbon Emissions Trading" on December 12, 2014, to take effect 30 days later, but there is no specific period of validity, which means that the measures will be implemented over the long term. The Guangdong Development and Reform Commission officially implemented "the Detailed Rules of Managing Carbon Emission Allowance" on March 1, 2015 and stipulated that the rule would be valid for 5 years. The regulations and policies implemented in compliance year 2014 were effective in compliance year 2015. To

determine changes in regulations and policies in 2015, here, comparison of the regulations and policies in the two stages is limited to analyzing the new regulations and policies published in compliance year 2015. The new policies and regulations related to the Guangdong carbon market are shown in Table 2.

As Table 2 shows, at the country level, there were a total of three policies related to the Guangdong carbon market in compliance year 2015, at the provincial level four, and at the exchange level three. At the country level, China has put forward comprehensive plans for ecological civilization construction, which include the contents of the carbon rights system and green finance, and has reached consensus with the USA and France, demonstrating a determination to actively participate in tackling climate change. At the provincial level, the Guangdong Provincial Development and Reform Commission made detailed provisions regarding the issuance of Guangdong carbon allowances for the 2015 compliance year and officially launched reporting of greenhouse gas emissions. At the exchange level, CEEX further optimized their trading rules and strengthened their ability to control trading risk, and in the meantime also opening up the business of buying back and mortgaging carbon allowances.

Comparing regulatory policies, we see that there were no major changes between the compliance years 2014 and 2015. The state released two documents about solving climate problems, which indicate that China is gradually paying more attention to ecological and climate change. The prospects for China's carbon market development remain bright, but in the compliance year 2015 there were no major influential laws or regulations released. Additionally, except for the four rules published by CEEX, no important and relevant laws or regulations were published at the provincial level; the only major difference was the "carbon allowance scheme", which may be one reason why the liquidity of the Guangdong carbon market changed in 2015. In addition, we can determine that Guangdong's carbon financing business has begun to improve and become standardized.

3.2.2 Carbon Allowance Scheme

Compliance year 2014

The total carbon allowance of Guangdong in 2014 was approximately 0.408 billion tonnes, including 0.37 billion tonnes for emission-controlled enterprises and 0.038 billion tonnes for reserve. The reserved allowances consisted of allowances for new business projects and allowances for market adjustments. There were in total 193 emission-controlled enterprises from the industries of power, cement, petrochemicals and steel, whose annual emissions exceeded 20 thousand tonnes of CO_2 (or comprehensive energy consumption equal to 10 thousand tonnes of standard coal). Additionally, 18 new business projects had the same emission standard as the emission-controlled enterprises after construction and operation. The allocation method of carbon allowances combined the baseline method and the historical method (Table 3).

Table 3 Calculation methods for carbon allowances of Guangdong's enterprises in 2014

	Baseline method		Historical emission method	
Applied enterprise	Electric power industry coal-fired gas generating set + Production and grinding of ordinary cement clinker in cement industry enterprise with long process in iron and steel industry		The other emission-controlled enterprises	
Calculation formula	Emission-controlled enterprise	Advance allowance = actual production in 2013 × benchmark value × annual decline coefficient (1) Certificated allowance = advance allowance × production correction factor	Emission-controlled enterprise	Allowance = historical average annual emissions × process flows × (annual decline coefficient + allowance (for upgrading of oil products in petrochemical enterprises))
	New project/enterprise	Allowance = designed capacity × benchmark value	New project/enterprise	Allowance = estimated annual comprehensive energy consumption × carbon emission reduction factor

Source http://www.cnemission.cn

Because of the special provisions regarding the output correction factor of coal-fired generators and gas generators, the actual allowance for the power industry is relatively less, and its need to expand capacity is somewhat limited.

Compliance year 2015

The total carbon allowance of Guangdong in 2015 was also approximately 0.408 billion tonnes consisting of 0.37 billion tonnes for emission-controlled enterprises and 0.038 billion tonnes for reserve (reserved allowances included allowances for new projects and market adjustments). The emission-control system covered 186 enterprises, whose emissions exceeded 20 thousand tonnes (or comprehensive energy consumption equal to 10 thousand tonnes of standard coal) and came from the four industries of power, steel, petrochemicals and cement. There were 31 enterprises with new projects, and the standard to be covered was the same. The allocation method of allowances adopted the baseline method and the historical method (details are shown in Table 4).

The specific allowance calculation methods for 2015 were almost the same as in 2014, and there was no special provision regarding the output adjusting factor of some of the industries and related processes. The allocation of allowances still combined the free and the paid, with the free allocation proportion of the power industry at 95% and for the other three industries at 97%.

Comparison

Comparing the Guangdong carbon market's allowance allocation system in compliance years 2014 and 2015, we see that the allowance allocations of the two years were generally similar but that there were also many differences in the details. Summaries of several major changes in Guangdong's carbon allowance allocation in compliance year 2015 are presented in Table 5.

3.2.3 Trading Rules

The Guangdong carbon market consists of the primary market and the secondary market. The annual trading scale of the primary market is significantly higher than that of the secondary market, but taking into account the few trading opportunities and large time intervals, the comparison here focuses mainly on the secondary market in compliance years 2014 and 2015.

(1) The common points of the two compliance years

The participants in the Guangdong carbon market in both years included emission-controlled enterprises, new projects, individuals, some approved investment institutions and other organizations. The market implemented a membership management system, and its products were GDEA and CCER. The transactions model adopted listing-order selection and transfer by agreement (the detailed process is shown in Fig. 3). The single order to list allowances above 100 thousand tonnes was required

Table 4 Calculation methods for carbon allowances of Guangdong's enterprises in 2015

	Baseline method		Historical emission method	
Applied enterprise	Electric power industry coal fired gas generating set + Coal-fired hot spot co production unit production and grinding of ordinal cement clinker in cement industry enterprise with long process in iron and steel industry		The other emission-controlled enterprise	
Calculation formula	Emission-controlled enterprise	Advance allowance = actual production in 2014 × benchmark value × annual decline coefficient (1) Certificated allowance = advance allowance × production correction factor	Emission-controlled enterprise	Allowane = historical average annual emissions × annual decline coefficient
	New project/enterprise	Allowance = designed capacity × benchmark value	New project/enterprise	Allowance = estimated annual comprehensive energy consumption × carbon emission reduction factor

Source http://www.cnemission.cn

Table 5 Changes in GDEA's allocation mechanism in compliance year 2015

Change 1	Change 2	Change 3
Emission-controlled enterprises increased from 2011 to 2017	Coal-fired cogeneration unit was brought into the scope of applying the baseline method	The amount of paid allowance was reduced from 8 million tonnes to 2 million tonnes
Change 4	Change 5	Change 6
Bidding of paid allowance implemented the policy reserved price to replace the auction base price	The restriction that enterprises could only buy carbon allowances from the primary market was eliminated	The process flow in some industries was eliminated

Source http://www.cnemission.cn

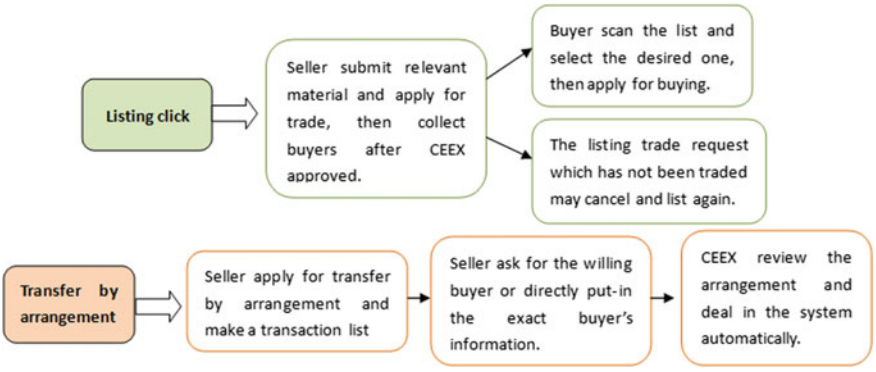

Fig. 3 Process of the listing-order selection model and the transfer by arrangement model. *Source* http://www.cnemission.cn

to use the model of transfer by arrangement, which differs from the listing-order selection model in that with less information to list, it previously had not needed to include the desired price and quantity. The opening price is the closing price of the last trading day, and price fluctuation is limited to 10%.

(2) The adjustments to trading rules in compliance year 2015

The 2015 transaction fee was changed significantly, and CEEX made other adjustments in the trading rules. On June 8, 2015, CEEX formally implemented many preferential measures for carbon trading, lowered its threshold and put forward features to attract and encourage investors to trade (shown in Table 6).

In comparison, there were many substantial changes to the trading aspect. The change in the calculation method of the closing price may have resulted in a more reasonable closing price to reflect the real market price and avoid manipulation risk. The transaction fee also had to be reduced dramatically with 60% less than

Table 6 CEEX trading rule adjustments comparison in 2015

	Closing price	Transaction fee	Transaction preferential	Account opening process	Listing and selection	Monitoring account	Membership preferential
The compliance year of 2014	Weighted average price of the last ten transactions	Charge 5‰ of the transaction amount on both sides	\	Open account on site with materials	1. Disorder list 2. Can only choose the lowest sell order and the highest buy order	\	\

(continued)

Table 6 (continued)

	Closing price	Transaction fee	Transaction preferential	Account opening process	Listing and selection	Monitoring account	Membership preferential
The compliance year of 2015	Weighted average price of all transactions in one day	Charge 2‰ of the transaction amount on both sides	Individual member: If traded quantity accumulated up to 3000 tons, the next year's annual fee can be exempted Institution member: If traded quantity accumulated up to 100 thousand, 50% of the next year's annual fee can be exempted, and a traing place worth 7000 yuan can be presented, too If traded quantity accumulated up to 200 thousands tons, the next year's annual fee is free, and 2 training places can be present	Open account remotely by mailing materials	1 List can be sorted automatically by time and price 2. Can only choose the lowest sell order and the highest buy order 3. Can avoid "wrong selection" that resulted from operational errors	Can apply for one account, and check the transaction record and instant quotes if in need	If joined in before June 30th, 2016, all kind's member can be exempted the membership fee and 50% annual fee

Source http://www.cnemission.cn

previously, which may have been very attractive to investors. In addition, many preferential measures for the Guangdong carbon market were implemented in 2015.

4 Comparison of the Market Liquidity of Guangdong's and Hubei's Carbon Pilots

The Hubei carbon market is a relatively special carbon market among the seven Chinese carbon pilots; it started very late, on April 2, 2014. Hubei has the most stable trading and price. As the Carbon K-line indicates, the price of the Hubei carbon market generally remained at approximately 25 yuan per tonne from when it began to November 30, 2015. The trading volume is also stable, and it was affected relatively little by the time span. Additionally, there were almost no trading days without any trading.

4.1 Trends in the Liquidity of the Hubei Carbon Market

Hubei's carbon allowance allocation method is more complicated than that of Guangdong, especially in the data and information, except for the CHEEX's announcement that Hubei only conducted one transfer of 2 million tonnes government reserved allowance in 2014 and there was no transfer of government reserved allowance in 2015. It is difficult to access the other data and information to calculate the MH index of the Hubei carbon market. As a result, this paper will scale up the index and substitute the market liquid allowance with the entire year's total allowance in 2014, representing the market liquid allowance with 1.1 times the entire year's total allowance in 2015. In this way, the calculated market liquidity may appear worse than in reality.

(a) **The trend of zero transactions**

On the market from April 2, 2014 to November 13, 2015, there were 390 trading days (excluding legal holidays and the temporary announced market closing day). There were no trading days without any transactions; its proportion of zero transactions in each month was zero per cent.

In the market's simple zero transactions trend, Hubei's carbon market was very active, with trading days with more or fewer transactions accounting for 100% of the total working days. There were no trading days without any transactions, which is in sharp contrast to Guangdong's carbon market. Hubei's carbon market performed well from this point of view, and the market was stable and had adequate liquidity.

(b) **The liquidity with non-fluctuating price**

During the period from April 2, 2014 to November 13, 2015, there were a total of 23 trading days as shown in Table 7. Hubei's carbon market was the same as

Table 7 Dates and quantities of HBEA flowing into the market

Trading date	Trading volume (tonne)	Trading date	Trading volume (tonne)	Trading date	Trading volume (tonne)
2014.05.25	43,977	2015.01.23	20,528	2015.06.02	121,856
2014.08.08	16,181	2015.01.28	13,608	2015.06.18	19,807
2014.10.31	18,275	2015.01.30	66,828	2015.06.19	660
2014.11.05	7639	2015.02.06	14,690	2015.06.24	17,500
2014.12.30	32,000	2015.03.27	25,337	2015.06.25	16,000
2015.01.08	5675	2015.04.07	57,100	2015.06.30	12,095
2015.01.14	8207	2015.04.23	15,795	2015.07.30	68,171
2015.01.21	27,029	2015.04.24	47,755		

Source http://www.cnemission.cn

Guangdong's in total trading days with non-fluctuating prices. However, the Guangdong carbon market started approximately 5 months before Hubei's, which means the Hubei carbon market had more trading days with non-fluctuating prices than Guangdong's in the same period and that Hubei's carbon price performed better than Guangdong's in price stability. In addition to the differences in price and trading days, the trading volume of Hubei's carbon market was more stable. Except for the minimum 660-tonne allowance, the trading volume of the other trading days all exceeded 5 thousand tonnes.

The trading volume of the Hubei carbon market's trading days with non-fluctuating price essentially remained at approximately 20 thousand tonnes; the maximum exceeded 120 thousand tonnes on June 2, 2015. Hubei's compliance period of the first compliance year was from July 2, 2015 to July 10, 2015; however, the market had no obvious "compliance phenomena" in the period before compliance. Therefore, Hubei's carbon market was generally stable and without periodic features.

(c) **The liquidity on a normal trading day**

As in the analysis of Guangdong's carbon market, after excluding the above two situations, the remaining trading days were all normal in terms of trading volume and price fluctuation. As a result, here, formula (1) can be used to measure the Hubei carbon market's liquidity. After eliminating the two extreme values of 3503.741 on November 12, 2015 and 21.5796 on March 4, 2015, the MH liquidity index trend of Hubei's carbon market can be shown as in Fig. 4.

In these circumstances, although the MH index has been scaled up compared with the actual values, the overall MH values remain very low. Except for the several extreme values, the maximum is 4, and after eliminating this value, most values are close to the "X-axis". In addition, from the MH index trend, we see no obvious regularities and that the index values from August to September slightly increased. The index values of early November 2014, late February 2015 and late August 2015 all have the trend of drastic inclines, but because there are too few of these values,

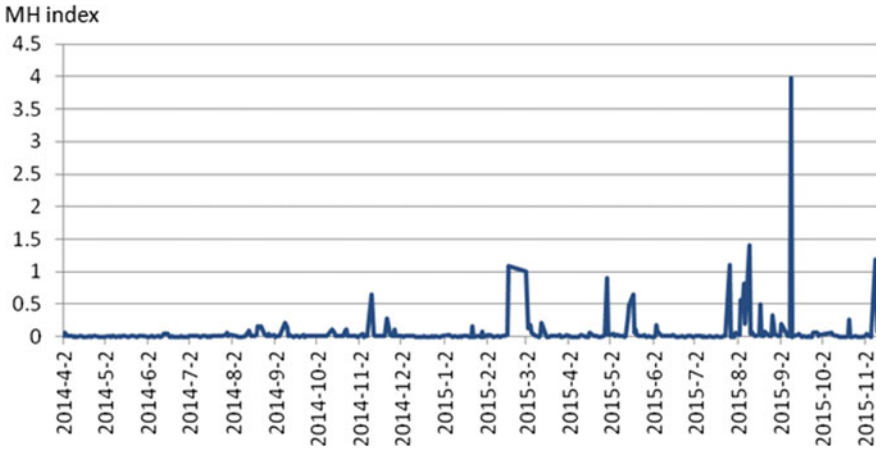

Fig. 4 MH Index trend of Hubei's carbon market. *Source* http://www.cnemission.cn

they are not quite representative. Therefore, the MH index values of Hubei's carbon market were relatively small and stable, which means the liquidity of Hubei's carbon market was adequate and stable.

4.2 Liquidity Comparison of the Guangdong and Hubei Carbon Markets

In general, Guangdong's carbon market was unstable and often had zero transaction trading days; its features included serious "compliance phenomena", great price fluctuation, and low exchange rate. After summarizing the liquidity analysis of the Guangdong carbon market from three different angles, we find that its overall liquidity was poor and there remained a large gap between it and Hubei's carbon market.

(1) Regarding the market's zero transaction days, Guangdong had a high proportion of such trading days each month, and the "zero transaction" proportion rose to 100%.
(2) For the liquidity with non-fluctuating price, Guangdong was the same as Hubei but owing to the late start of Hubei's carbon market, Guangdong's still lagged behind Hubei's in market stability.
(3) Except for the above two circumstances, on normal trading days, even when Hubei's MH index values were scaled up, they were still lower than Guangdong's. Guangdong's MH index values were too high, at almost ten thousand or one million times Hubei's MH index.

4.3 Comparing Influencing Liquidity Factors Between the Two Carbon Markets

4.3.1 Laws, Regulations and Policies

Relevant regulations and policies for the Hubei carbon market

According to the policies, laws and regulations listed in Hubei's carbon emissions trading centre bulletin, most of the policies and regulations are at the provincial level and only two were promulgated by the Hubei carbon emission exchange. This may have resulted from the provincial government's heavy dominance of Hubei's carbon market and the relatively strong attachment of Hubei's carbon emission exchange to the provincial government. Policies and regulations applying to the Hubei carbon market are shown in Table 8.

On the provincial level, Hubei put forward general requirements about the distribution and management of emission allowances, market trading, MRV systems and the incentive-constraint mechanism, while the allowance allocation method was also described in detail. In addition, the "Low-Carbon Development Plan of Hubei's

Table 8 Laws, regulations and policies of the Hubei carbon market

Province level	"Interim Measures for the administration and trading of carbon emission rights in Hubei Province"	April 4, 2014
	"The scheme of carbon allowance in Hubei Province"	April 14, 2014
	"Guidelines for the verification of greenhouse gas emission in Hubei Province (for Trial Implementation)"	July 24, 2014
	"Guidelines for the detection, quantification and reporting of greenhouse gas emissions from industrial enterprises in Hubei Province (for Trial Implementation)"	
	"Hubei Province low-carbon development plan of energy saving and emission reduction in 2014–2015"	October 27, 2014
	"Notice of the provincial development and Reform Commission on the relevant matters concerning the carbon emission right offset mechanism in Hubei Province in 2015"	April 17, 2015
	"Measures for the administration of Hubei Province on carbon emission allowance release and repurchase (for Trial Implementation)"	September 28, 2015
Exchange level	"Rules for the implementation of the carbon allowance custody business in Hubei Province (for Trial Implementation)"	December 8, 2014
	"Trading rules for carbon allowance in Hubei Province"	December 11, 2014

Source http://www.cnemission.cn

Energy saving and Emission Reduction" set a goal of 3.4% reduction in carbon emissions per GDP.

Comparison with Guangdong

In terms of carbon emission reduction targets, the "Guangdong Provincial Plan of Energy Saving and Carbon reduction for 2014–2015" set a reduction goal of more than 3.5% for carbon emission per GDP, which is basically consistent with Hubei Province. Guangdong also formally implemented the provincial regulation "Pilot Measures for the Administration of Carbon Emission in Guangdong Province" on March 1, 2014; considering the different starting dates of the two markets, this was relatively late for Guangdong to publish provincial carbon regulations. Additionally, the one major difference between the two markets is the disposal method of residual carbon allowances. Hubei provides that a residual carbon allowance that has not been traded must be cancelled in the compliance period and cannot be held by an enterprise itself, while Guangdong allows enterprises to withhold a residual carbon allowance and use it for the following year's compliance.

4.3.2 Carbon Allowance Scheme

Hubei Province

Hubei had a total of 0.324 billion tonnes carbon allowance in compliance year 2014, which consisted of the initial allocation allowance, the reserved allowance for adjustment and the government's reserved allowance. The concrete calculating methods are as follows:

- The initial allowance = total carbon emission of enterprises in 2010 × 97%
- The government's reserved allowance = total carbon allowance × 8% (includes 30% for public bid)
- The reserved allowance for adjustment = total carbon allowance − the initial allowance − government's reserved allowance

The initial allowance is freely issued to enterprises at one time early in the compliance year, while the reserved allowance for adjustment is issued after enterprises complete their emission verification before compliance. The government's reserved allowance is mainly used to adjust the supply and demand of allowances and further maintain market stability. On March 31, 2014, the 2 million tonnes of Hubei government's reserved allowance was successfully bid, and the base price was 20 yuan per tonne allowance.

If the actual carbon emission and the initial allowance differ more than 20% or 2 million tonnes, enterprises are allowed to apply to change their initial allowance (the detailed calculation methods are shown in Tables 9 and 10).

Table 9 Carbon allowance calculation method of Hubei's emission-controlled enterprises in 2014

Industry	Calculation formula
Electric power industry (baseline method)	Total amount of carbon allowance = advance allowance ± post-regulation allowance Advance allowance = historical base emission × adjustment coefficient 0.9192 × 50% Post-regulation allowance can be divided into additional allowance and collected allowance Additional allowance = excess generating capacity × benchmark value (99.193 tonnes/thousand kilowatt hours for thermal power, combined heat and power, coal gauge power generation enterprises adopt the emission of unit power generation in the exact year) Collected allowance = residual electricity generation × carbon emissions of unit power generation
Non-electric power industry (historical method)	Initial allowance of the compliance year = historical base emission × adjustment coefficient 0.9192

Source http://www.cnemission.cn

Table 10 Calculation method of adjusted allowance of Hubei's emission-controlled enterprises in 2014

Difference of more than 20% between actual carbon emissions and the annual initial allowance:
Additional allowance = actual carbon emission-initial allowance × 120% Collected allowance = initial allowance × 80%-actual carbon emission
Difference of more than 200 thousand tonnes between actual carbon emissions and the annual initial allowance:
Additional allowance = actual carbon emission-initial allowance-200 thousand tonnes Collect allowance = initial allowance-actual carbon emission-200 thousand tonnes

Source http://www.cnemission.cn

Comparison with Guangdong

In terms of setting the total carbon allowance, Guangdong Province allows more than that of Hubei. The Guangdong government's reserved allowance accounts for 9.3% of the total allowance, 1.3% higher than that of Hubei, and the allowance used for public bidding is also more than that in Hubei. Additionally, both Guangdong and Hubei adopt the allocation method of rolling the base three years but taking account of the different industrial structures and Hubei's rapidly growing economy, Hubei's

carbon allowance is relatively tight. One significant reason for the heightened activity in the Hubei carbon market is its tight carbon allowance; the calculated allowance in accordance with the base year is obviously inadequate for the economic reality.

4.3.3 Trading Rules

Hubei's carbon market consists of a primary market and a secondary market. However, the secondary market is considered as the main component, whereas there is only one auction in the primary market. The following focuses mainly on analyzing the secondary market.

Hubei's carbon trading rules

Hubei's primary market also chose auction as the only transaction mode; however, the allowance that has been traded comes from the government's reserved allowance. In terms of the market openness, Hubei's primary market is opened to enterprises, investment institutions, and social and individual investors. In terms of the auction price, Hubei set a price as the base trading price in compliance year 2014, which is the same as Guangdong. The base price "20 yuan per tonne" is very close to the secondary market. However, Hubei only conducted one auction in compliance year 2014.

For the secondary market, the participants include domestic and foreign investment institutions, carbon emission-controlled enterprises, organizations and individuals, all managed by the membership management system of CHEEX (see Table 11). Until October 30, 2015, the Hubei carbon market had a total of 6,292 investors. The market uses the mixed transaction mode of "pricing transfer" and "negotiated transfer", and all transactions must declare their trading demand through the trading system. In the meantime, the allowance quantity that individuals hold cannot exceed 1 million tonnes.

Table 11 Transaction mode of Hubei's secondary carbon market

Negotiated transfer	Pricing transfer	
"Negotiated transfer" implemented the non-continuous trading forms; 5 min is a complete period, the previous 4 min is for declaration and the last 1 min is for negotiation and report. The price can fluctuate in the range of 10% above and below of the last trading day's closing price	Public transfer	Transfer by arrangement
	1. Fixed price 2. List first and then wait for transaction order 3. According to the principle of price priority	1. The same as Guangdong's transfer by agreement 2. Take the same 10% price fluctuation range with public transfer

Source http://www.cnemission.cn

The opening price of Hubei's secondary carbon market is the price of the first transaction, and the closing price is equal to the weighted average of the prices in the last 10 trading periods. If there has been no transaction in the last 10 trading periods, the closing price is represented by the last transaction of the trading day. In terms of the transaction costs, individual and institutional investors are free to open an account, broker members who joined before September 30, 2015 are exempt from the membership and annual fees, and the brokerage commission ratio will gradually increase from 50% to 90% along with its transaction size. Additionally, there are two notable features of the handling fee. First, the handling fee of negotiation and bargaining does not exceed 5% of the total trading amount on both sides. If the total handling fee reaches 100 thousand yuan or one must pay a handling fee of 100 thousand yuan at one time, investors can request a fee waiver. Second, the handling fee of a pricing transfer is 4% of the total trading amount on the single seller.

Comparison with Guangdong

First, the source of allowance for auction in Hubei differs from that in Guangdong's for auction comes from the allowance of enterprises which carbon emission is controlled. For the primary market in Guangdong, individual investors are not allowed to participate, and the conditions of institutional investors entering the primary market are somewhat strictly regulated.

Second, based purely on Hubei's carbon market, although there is only one auction in the primary market, the secondary market liquidity has been very stable and adequate. Therefore, the primary market may have limited influence on market liquidity.

Third, the auction price of Hubei's primary market is close to that of the secondary market, which is similar to that of Guangdong after Guangdong established the link between the primary market price and the secondary price. We could infer that the primary market price may have greatly influenced the carbon market liquidity.

Fourth, participants in the Guangdong and Hubei secondary carbon markets are essentially similar, including enterprises, institutional investors and individual investors.

Fifth, the daily price limits in Guangdong and Hubei are basically consistent; the price limit of "negotiated transfer" in the Hubei carbon market is, as in Guangdong, 10%. The price limit of "pricing transfer" is different at 30%. Hubei has not restricted institutional investors buying allowances; the only restriction is that individual investors must hold allowances of less than 1 million tonnes. However, Guangdong has placed restrictions on their institution investors and individuals, with the maximum holding allowance 3 million tonnes.

Sixth, in terms of the transaction costs, Hubei has lower costs than Guangdong. Hubei has not only allowed institutions and individuals to open accounts freely but also implemented relief measures on account, annual and handling fees. The gradient commission discount, in particular, is more conducive to encouraging members to trade and further stimulated its carbon market.

4.3.4 Carbon Finance

While Guangdong's carbon finance is more focused on enterprises' compliance and financing, Hubei's carbon finance is more diverse and with a variety of functions (see Table 12). Regarding carbon funds, which can effectively drive market trading, Guangdong also differs from Hubei. Guangdong's carbon fund is government-oriented and with low marketization. Private capital has not fully attracted participation in carbon trading, which may be related to the different positioning of the two carbon markets.

In terms of time, the progress of developing carbon finance in Guangdong Province is relatively slow compared with that in Hubei Province. Guangdong has launched only four carbon financial products in the 2 years since it started. Although Guangdong established a carbon fund, it is still too dependent on the provincial government to promote the needed degree of marketization and operate it successfully. Hubei's carbon finance has been blossoming everywhere from the beginning of the market, achieving successful operation of the carbon emission right pledge loan, carbon fund, carbon asset custody, carbon financial credit and carbon bond in only several months.

In terms of the scale of products, Hubei has promoted many carbon emission right pledge loans for a total of 0.54 billion yuan over one year, while Guangdong has just finished once for a total of 5 million yuan. The pledge loan activity in Guangdong is still far from that in Hubei. For the other three financial products of Guangdong's carbon market, no corporation has used the carbon trading corporation overdraft since it was launched. As the new carbon financial products of Guangdong, the carbon allowance repurchase and EA-SCP are very important mechanisms.

5 Conclusions

Comparing its own performance over time, the liquidity of Guangdong's carbon market has had obvious compliance phenomena in the previously discussed 2 compliance years. Liquidity was relatively better during the period around compliance, but on normal trading days it was extremely poor. In compliance year 2015, there were signals that the market liquidity might change and improve. But compared with Hubei Province, owing to the obvious inadequate liquidity, there remained much room for Guangdong to improve its carbon market liquidity. Through the comparison of market liquidity and its influencing factors from historical and lateral perspectives, this paper draws the following conclusions:

First, because the Guangdong carbon market did not publish many policies and regulations in compliance year 2015, the liquidity was contrary to the usual trend and performed successively better in the months after the last compliance period. This change indicates that there is no great relevance of policies and regulations to the liquidity of Guangdong's carbon market as well as those policies and regulations may not be the main reasons for the improvement in the market's liquidity. Therefore,

Table 12 Carbon finance methods: Hubei versus Guangdong Province

Guangdong Province		Hubei Province	
Product	Practical case	Product	Practical case
Carbon Emission Allowances Mortgage Financing	On 2014 December 25, Guangzhou University City Huadian new energy company mortgage its own 15 million tons carbon emission allowance to the Shanghai Pudong Development Bank Guangzhou Branch and acquired also an of 5 million yuan	Carbon Emission Right Pledge Loan	1. On September 19th, 2014, Hubei Yihua Group got loans from Industrial Bank of 49 million yuan by mortgaging its 2.1 million tons emission allowance 2. On November 25th, 2014, China Construction Bank Hubei Branch signed an agreement of 0.3 billion yuan with Wuhan Huaneng Power Generation Co., Ltd. Meanwhile. Everbright Bank Wuhan Branch signed an agreement of 0.1 billion yuan with Hubei JinAo Chemical Technology Co., Ltd. 3. On August 25th, 2015. China Import and Export Bank Hubei branch signed an agreement of 0.1 billion yuan with Hubei Yihua Group
Carbon Trading Coloration overdraft	On 2014 December 25, Guangzhou University City Huadian new energy company acquired a carbon trading corporation overdraft of 5 million yuan from Shanghai Pudong Development Bank Guangzhou Branch	Carbon Fund	Hubei public the China first carbon market fund on November 26th 2014. Huaneng Group and Lion Fund management Co., Ltd jointly issued the scale of 30 million "carbon emissions permits special asset management plan" fund aiming to invest in allowance trading

(continued)

Table 12 (continued)

Guangdong Province		Hubei Province	
Product	Practical case	Product	Practical case
Carbon Allowance Repurchase	\	Carbon Crowd-funding	On July 24th, 2015, CHEEX raised 0.2 million yuan in 5 min, which was use for CCER development of rural biogas digesters. This project helped the farmers increase income by revitalizing their carbon asset and benefit the investors with CCER emission reduction or certificate of honor
EA-SCP	\	Carbon Asset Custody	1. On December 8th, 2014. Hubei Xingfa Chemical industry Co., Ltd successfully entrusted its 1 million's tons carbon allowance 2. On December 22nd, 2014. Hubei Yihua Group signed agreement to entrust its 1.008 million tons carbon allowance
Low-carbon Development Fund	On October 26, 2015, Guangdong provincial development and Reform Commission and provincial finance department arranged 100 million yuan's low-carbon development fund, and commissioned Guangdong Yueke Financial Group Co., ltd. to manage	Carbon Financial Credit	By the end of November, 2014. Hubei has signed credit agreement of the "low carbon industry development and Hubei carbon financial center construction" with China Construction Bank, Minsheng Bank, Shanghai Pudong Development Bant and the Industrial Bank, the total size has reached 800 billion yuan

(continued)

Table 12 (continued)

Guangdong Province		Hubei Province	
Product	Practical case	Product	Practical case
		Carbon Bond	On November 26th, 2014, Minsheng Bank Wuhan Branch signed the domestic largest carbon bonds intentionality cooperation agreement with Hubei Huadian Power Generation Co,. Ltd for 2 billion yuan

Source http://www.cnemission.cn

policies and regulations cannot effectively stimulate enterprises to participate in market trading and are not entirely conducive to enhancing the liquidity of Guangdong's carbon market.

Second, methods of calculating and issuing carbon allowances are some of the main factors influencing the liquidity of the Guangdong carbon market. Guangdong has made several adjustments to its carbon allowance scheme, such as increasing the quantity of emission-controlled enterprises, expanding the scope of industries that suit the baseline method, reducing the quantity of paid allowance, cancelling the base bidding price and linking the price of the primary market and the secondary market, and abandoning the limitation that enterprises could only buy allowances from the primary market. These many measures together made the participants in Guangdong's carbon market more diverse and the relationship of supply and demand more balanced. Consequently, the liquidity of Guangdong's carbon market has improved. However, compared with Hubei ETS, the total allowances of Guangdong are still relatively loose and the enterprises rather concentrated.

Third, the microstructure of Guangdong's carbon market is another factor greatly influencing its liquidity. The implementation of linking the prices of the primary and secondary markets in Guangdong was helpful in reducing the fragmentation of the two markets, which as a result improved the expectations of enterprises and institutional investors of the secondary market and their participation in it. After CEEX launched a series of preferential measures on transactions, the attractiveness of the secondary market to investors was further enhanced. Additionally, comparing the trading rules of Guangdong and Hubei, Hubei's barriers to market entry are quite low, and Hubei has crafted extremely attractive trading incentives. Creating a huge scale of individual investors and institutional investors may be the main reason why Hubei's market activity exceeded Guangzhou's. Therefore, although the factors influencing investors to participate in the Guangdong carbon market vary, in terms

of expanding the number of participants, the effectiveness of Guangdong's relevant measures is still not obvious.

Fourth, financial innovation that Guangdong undertook in compliance year 2015 was not the main factor influencing improvements in its carbon market. From a historical perspective, Guangdong is speeding up its carbon financial innovation, launching two carbon financial products at the same time and greatly making up for its previous lagging behind on carbon finance. However, whether or not the two products were launched and how the market liquidity performed have no obvious positive correlation characteristics. Comparing the carbon finance of Guangdong and Hubei, there is no doubt that the development of carbon finance has a great influence on the market liquidity. Hubei's carbon financial products are diverse and involved in low-carbon financing, carbon asset management, market trading and the other aspects. Each product has been operated successfully on a considerable scale, and many carbon financial products were developed hand in hand. Consequently, a virtuous cycle of carbon market and carbon finance has been created. This may be the main reason for the large difference in liquidity between Guangdong and Hubei. Therefore, Guangdong's carbon financial structure must be optimized and scaled up.

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