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Assessing the maturity of China's seven carbon trading pilots

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Abstract

Indicators based on the developed version of the Capability Maturity Model were set up to access the maturity degree of China's seven pilot carbon markets from 2013 to 2017. Results show that the maturity degree of Shenzhen and Beijing pilot carbon markets ranks first; while those of Guangdong, Hubei, and Shanghai rank second. Tianjin and Chongqing rank lowest. Most of pilot markets failed to perform well on price efficiency except Shenzhen. There is significant disparity in the scores that the pilot carbon markets got, with a range from 9 to 73. The drivers to maintain market maturity is different among the pilot markets, either with a good performance on market structure, scale, or efficiency could lead to a certain score. Much could be done to increase the maturity level of the carbon market. Further downscaling the firm size, raising the legislation level, and increasing the participation of the third party entities may help the carbon market to grow healthier.

Keywords: China; Carbon market pilots; Maturity assessment; Market structure; Market scale; Market efficiency

1. Introduction

Climate change is one of the major challenges faced by human beings in the 21st century. The IPCC Fifth Assessment Report stated that human-emitted greenhouse gases (GHGs) are extremely likely to be responsible for more than 50% of global warming that has occurred since 1951 (IPCC, 2014). Currently, China is the largest emitter of GHGs in the world. China's CO_2 emissions reached 9.1Gt in 2016, while CO_2 emissions from the EU and the U.S. totaled 8 Gt in the same year (IEA, 2018). China's carbon emissions continue to increase in contrast to the total carbon emissions of the EU and the U.S., which are already in the process of a long-term decrease. To promote investments and reduce GHG emissions, China's National Development and Reform Committee (NDRC) launched the notice of commencement of the Carbon Emission Trading Pilot Scheme, selecting Beijing, Shanghai, Tianjin, Shenzhen, Chongqing, Guangdong, and Hubei as the pilot cities/provinces (NDRC, 2011). In addition, the NDRC implemented the National Carbon Emission Trading Scheme (ETS) on China's National Carbon Market at the end of year 2017 (NDRC, 2017).

Compared to other carbon markets such as the EU ETS, China's carbon market is still in its initial stage. Studies were mostly based on qualitative analysis or comparative studies on the pilot cities, which were lack of sufficient systematically quantitative support (Clayton et al., 2016; Fu et al., 2014; Yang, 2013). Although different dimensions, for example, the market scale, market structure, the market risks, and the maturity level, are used to assess different aspects of the pilot carbon markets in China (Liu et al., 2015; Xie et al., 2017), they are lack of either comprehensive analytical structure or strong quantitative argument and only discuss the importance of structuring issues in the construction of carbon markets. Some works addressed the regulatory and management aspects and concluded that the pilot designs meet many challenges (Liu et al., 2015; Pan, 2016). However, few of these studies explored the market outcomes of policy intervention.

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Cong and Lo (2017) and Hu et al. (2017) conducted quantitative analysis on financial performance targeting single pilot market, such as Beijing and Shenzhen. Cong and Lo (2017) and Ibikunle et al. (2016) found that most of the pilot carbon markets in China still lack liquidity for reasons that need further discussion, where they went directly to the financial data details with limited overview of other impact factors. At a certain stage of market development, the price performances, information, and traders' behaviors differ considerably. Thus, a systematic assessment on the pilot carbon trade zones will help the administration sections and other countries develop ETS (Gu, 2015).

The seven pilot carbon markets are different in the designing steps, differentiated measurement, reporting, and verification systems and uneven in legislation systems (Pan, 2016). Comparing all of them in an integrated evaluation system is meaningful. Only a systematical model and multiple index system can perform well in the assessment of these pilot carbon markets. Therefore, we employ a maturity model and developed a corresponding indicator system to analyze and access the pilot carbon markets. Hence, we employ this maturity model for three main reasons. Firstly, it is an integrated model that can envelope all the relevant aspects we need to embrace in this study. Secondly, all relevant indicators, leaner or non-leaner, could be embedded into this model. Thirdly, the model could cover all the pilot carbon market zones in one study.

2. Methodology and data

2.1. Structure and indicators

The Capability Maturity Model (CMM) proposed by the Carnegie Mellon University's Software Engineering Institute, is the prototype model, from which all other maturity models were derived (Paulk et al., 1993; Paulk, 1993). Originally, the CMM was designed to evaluate the capabilities and "maturity" of an organization with regards to its software development processes. From then, it has been extended and customized for use in many sectors to measure the maturity level in a meaningful manner. CMM enables stakeholders to clearly identify strengths and improvement points and accordingly prioritize the tasks required to improve the maturity levels (Proença and Borbinha, 2016).

The maturity levels are a series of sequential levels, which collectively form an anticipated or desired logical path from an initial state to a final state of maturity (Röglinger and Pöppelbuß, 2011). Maturity models are tools being used to evaluate the maturity capabilities of certain elements, and to select the appropriate actions for bringing the elements to a high level of maturity (Kohlegger et al., 2009). Most maturity models are used in quite diverse domains, such as software engineering, asset management, and information governance (Koshgoftar and Osman, 2009). In China, most maturity assessments and studies focus on specific areas of market maturity evaluation, such as stock market (Bao, 2015), land market (Yu, 2008), labor market (Tian, 2016), and logistics market (Yi, 2011). Normally, a two-dimensional matrix exists, representing the level of market maturity and the evaluating aspects. Thus, the choice of indicators for each evaluation aspect differs based on the specific case. In this sense, this study follows the principal logic of the CMM and develops a two-level-indicator evaluating structure for China's case.

The first level indicators represent three aspects, namely market scale, market structure, and market efficiency. We have compared the former studies using CMM to evaluate the maturity of a sectoral market (Bao, 2015; Yu, 2008; Tian, 2016; Yi, 2011), where they select the first level aspects according to product life-cycle theory, price-cycle theory, market cycle theory and economic-cycle theory. Clayton et al. (2016) showed aspects to be considered in the establishment of a national carbon market. Previous study on the maturity level of China's carbon market provides an analytical structure without an empirical study (Liu et al., 2015). As the carbon market is similar to the financial market, we choose the above three aspects as the first level indicators (Table 1). The market scale reflects the capability of a market to provide sufficient competition. A larger market scale means larger competition. The market structure ensures that there is healthy growth of the market on a long-term scale. Additionally, the market efficiency reflects the operation performance.

The second level indicators under the market scale include the number of firms under control, the proportion of total

Table 1
Indicator system of the maturity model.

Aspect	Indicator	Implication
1 Market scale	1.1 Participants	The number of firms under control
	1.2 Emission coverage	The proportion of total carbon emissions covered (%)
	1.3 Quantity	The quantity of trade (Mt)
	1.4 Volume	The volume of trade (million CN¥)
2 Market structure	2.1 Third party	The number of third party entities
	2.2 Legislation	The level of administrative authority involved in signing off the legislation document
	2.3 Industry coverage	The number of industries covered
	2.4 Firm size	The size of controlled firms
3 Market efficiency	3.1 Price level	The average price within the collected range (CN¥)
	3.2 Valid trading days	The proportion of valid trading days in the operation duration
	3.3 Price effectiveness	The level of effectiveness of the price
	3.4 Complexity of products	The number of the carbon emission trading products

Table 2
Data sources for indicators 1.3 quantity, 1.4 volume, 3.1 price level, 3.2 valid trading days, and 3.3 price effectiveness.

Pilot	Data source	Period	Trading days (d)	Valid trading days (d)
Beijing	China Beijing Environment Exchange http://www.bjets.com.cn/article/jyxx/	2013.11.28–2018.02.09	1231	659
Tianjin	Tianjin Emissions Exchange http://www.chinatcx.com.cn/tcxweb/pages/trading/trading_hq.jsp	2013.12.26–2018.02.09	1203	461
Shanghai	Shanghai Environment Energy Exchange http://www.cneeex.com/sub.jsp?main_colid=224&top_id=218	2013.12.19–2018.02.09	1210	655
Chongqing	Chongqing Carbon Emissions Trading Centre http://tpf.cqggzy.com/index.html	2014.06.19–2018.02.09	1393	1348
Shenzhen	China Emissions Exchange (Shenzhen) http://www.cerx.cn/information/index.htm	2013.06.19–2018.02.09	1028	249
Hubei	China Hubei Emission http://www.hbets.cn/index.php/index-show-tid-13.html	2014.04.02–2018.02.09	1210	741
Guangdong	China Emissions Exchange (Guangzhou) http://www.cnemission.com/article/hqxx/	2013.12.19–2018.02.09	1106	892

carbon emissions covered, the quantity of trading emissions, and the volume of trading deals. For each of these indicators, higher values indicate a larger market scale.

A more complex market structure shows higher stability. There are four second level indicators in the market structure. 1) The number of third party entities. More third party entities indicate a better structure. 2) The level of the administrative authority involved in signing off the legislation documents. The higher the levels the more stable the markets are. 3) Industry coverage. More industries show greater disparity in carbon productivity. And 4) The size of the controlled firms. Small firms provide more innovative technologies in carbon reduction, hence when smaller firms were included, the market shows more stable performance.

The market efficiency reflects the activity of a market. An efficient market has clear information, which means it could find a price that should be stable enough to go up and down around the true value of the products. The price can send good signals into the market and to the substitute and complement markets. There are four second level indicators of market efficiency. 1) Price level. Among the seven pilot markets, a stable average price is essential for market efficiency, while a higher price presents a higher carbon value. 2) The proportion of valid trading days. More valid trading days indicates a higher number of activities in the markets. 3) Price effectiveness. A random price is effective. The unit root test can be used to determine whether the price is random. Without a unit root, the price is considered effective. 4) Complexity of products, an efficient market can facilitate trade in a wide product variety.

The levels of market maturity can then be defined as following.

Level 1: A pilot market. At this stage, a carbon market could present a carbon price that does not really reveal the true value of the carbon property. The trading is not voluntary. The proportion of the controlled participating firms is not high. Statistically, there is a relatively small trading scale, a just establishing market structure, low market efficiency, underdeveloped market function, and poor quality of the participating firms in free trade.

Level 2: A standardizing market. In this period, the maturity level of the market is growing. More firms are realizing the function of a carbon market and thus begin to learn and adapt to its rules. All indicators are increasingly which indicates the market is more capable of free trades.

Level 3: A mature market. A mature market could reveal the real value of carbon property, and could also influence the relative market and behaviors of the controlled firms. It will especially help to enhance the awareness of low carbon

Table 3
Augmented Dickey–Fuller test for indicator 3.3 price effectiveness.

Pilot	Price of allocated emissions	*T* value of Augmented Dickey–Fuller	Probability	Has a unit root (1 yes, 0 no)	Indicator 3.3 price effectiveness
Beijing	$P_{Beijing}$	−3.49	0.0083	0	1.0
	$P_{Beijing}^{a}$	−44.60	0.0001	0	
Tianjin	$P_{Tianjin}$	−1.28	0.1850	1	0.5
	$P_{Tianjin}^{a}$	−44.55	0.0001	0	
Shanghai	$P_{Shanghai}$	−2.20	0.21	1	0.5
	$P_{Shanghai}^{a}$	−40.81	0.0000	0	
Shenzhen	$P_{Shenzhen}$	−2.99	0.0369	0	1.0
	$P_{Shenzhen}^{a}$	−41.02	0.0000	0	
Chongqing	$P_{Chongqing}$	−1.68	0.4390	1	0.5
	$P_{Chongqing}^{a}$	−34.81	0.0000	0	
Guangdong	$P_{Guangdong}$	−2.14	0.2279	1	0.5
	$P_{Guangdong}^{a}$	−37.90	0.0000	0	
Hubei	P_{Hubei}	−2.29	0.1757	1	0.5
	P_{Hubei}^{a}	−44.46	0.0001	0	

Note: P means price. [a] means the first order difference time series.

development and improve the application of technology and research for a low carbon transformation in the whole industry.

It is not easy to figure out the exact boundaries from one maturity level to the next. We try to make a comparison among seven pilot markets, and the results of the analysis are a reflection of this comparison. Hence, instead of evaluating an absolute value, we only need the comparable results among the seven pilot carbon markets. Therefore, we allocate 100 points equally to each of the 12 indicators, where every indicator has an equal weight. Thus, the ranking order and the score gaps representing distances between two markets, are more meaningful than the absolute scores. A market with a final score equal to or above 80 is considered to be in quite a mature stage; for a final score above 60, the market can be classified into a medium mature stage from the pilot stage. If the final score is between 30 and 60, the pilot market is still in its pilot stage. If the final score is below 30, the market is probably not a best practice as a pilot.

2.2. Data and sources

We collected all relevant data from open sources on the database of each pilot carbon market and local provincial and municipal government websites. The sources of data relating to indicators 1.3, 1.4, 3.1, 3.2, and 3.3 are listed in Table 2. Moreover, the sources for indicator 1.1, 1.2, 2.1, 2.2, 2.3, 2.4, and 3.4 are collected from the legal documents from local authorities.

Here we want to make some specific introductions on indicators 2.2, 3.3, and 3.4. During the data collection for indicator 2.2 on legislation, all the pilot markets are under well-structured legislation systems. If we use the "whether or not" data to represent this indicator, no differences will be observed among the seven pilot markets. To avoid invalid indicators, we use the level of legislation to represent indicator 2.2. We have noticed three levels of legislation in the carbon market. A market that is under a formal and binding legislation and is approved by the provincial or municipal People's Congress was given a score of 3/3. If the market is under an executive order given by the provincial or municipal government, we give it a 2/3 score. However, if it is under an administrative regulation from a low-level department, we give it a 1/3 score.

In the case of indicator 3.3 on price effectiveness as it is in the market theory, the price would come randomly above 0 in an efficient market. Thus a unit root test, namely the Augmented Dickey–Fuller (ADF) test on the time series of carbon prices, is used to test the results. If the carbon price of a pilot market passes the unit root test, which means that the carbon price does not have a unit root, the market price is effective. Otherwise, the carbon price is ineffective. If the carbon price in a pilot market does not have a unit root on the original time series, the market obtains a score of 1. If the carbon price in a pilot market does not have a unit root on the first order difference time series, this market achieves a score of 0.5. Otherwise, it obtains a score of 0. Using the econometric software E views Version 7.2, the ADF test results for indicator 3.3 are listed in Table 3.

Indicator 3.4 is composed of the number of free allocated emissions, auctioned-allocated emissions, Chinese Certified Emission Reductions (CCERs), and carbon emission futures (Table 4). More products would provide the trading entities with more choices to find a good price for compensating the cost of carbon emission reduction.

To compare the indicators and obtain the final score as the results of the maturity level, we normalize the data of all the 12 indicators (Table 5) to get the weight of each indicator across all the seven pilots. Once the evaluating data matrix is normalized, we allocate 100 scores to each indicator with the same weight and distribute the scores of each indicator among seven pilot markets with the weights gained from the normalization. The scores of all the indicators in each pilot market are then added up and then the final evaluating score of the pilot markets are obtained.

3. Results

3.1. General results on maturity degree

The results show that none of the seven pilot carbon markets in China has obtained a maturity degree score higher than 80, with Shenzhen ranking the first with a score of 73, Beijing ranking the second with a score of 61. Chongqing ranks the lowest with a score of 9, and Tianjin ranks the

Table 4
Data for indicator 3.4 complexity of products.

Product	Beijing	Tianjin	Shanghai	Shenzhen	Chongqing	Guangdong	Hubei
Allocation	BEA	TJEA	SHEA	SZA2013 SZA2014 SZA2015 SZA2016 SZA2017	CQEA	GDEA	HBEA
Volunteering	CCER	CCER	CCER	CCER	CCER*	CCER	CCER
Trade off	Forest carbon sink	NA	NA	NA	NA	NA	NA
Futures	NA	NA	SHEAF022017 SHEAF052017 SHEAF082017 SHEAF021117	NA	NA	Futures contract	HBEA1705
Number of products	3	2	6	6	1.5	3	3

Note: * means data on the trading price and volume are not available but observed CCER trading regulations are in the documents of the pilot carbon market in Chongqing. NA means not applicable.

Table 5
Data for other indicators.

Indicator	Beijing	Tianjin	Shanghai	Shenzhen	Chongqing	Guangdong	Hubei
1.1 Participants (number)	947	114	190	636	242	189	29
1.2 Emission coverage (%)	50	60	50	40	40	60	45
1.3 Quantity (Mt)	7.16	3.01	10.19	24.55	7.51	34.20	49.21
1.4 Volume (million CN¥)	361.03	41.16	229.95	679.58	29.94	491.74	915.40
2.1 Third party (number)	26	4	10	28	11	29	8
2.2 Legislation (level)	2/3	1/3	2/3	3/3	1/3	2/3	2/3
2.3 Industry coverage (number)	7	6	7	2	6	6	10
2.4 Firm size (level)	1/0.5	1/2	1/2	1/0.3	Na	1/2	1/6
3.1 Price level (CN¥)	50.51	20.73	26.85	48.10	18.94	26.77	20.63
3.2 Valid trading days (proportion)	0.54	0.38	0.54	0.97	0.24	0.61	0.81
3.3 Price effectiveness (level)	1.0	0.5	0.5	1.0	0.5	0.5	0.5
3.4 Complexity of products (number)	3.0	2.0	6.0	6.0	1.5	3.0	3.0

second but the last with a score of 17. Guangdong, Shanghai and Hubei rank in the middle with respective scores of 47, 43, and 35. Fig. 1 displays the results of the maturity degrees of the seven pilot carbon markets. The figure is leaning to the dimension of market efficiency, with short ends on the dimension of market scale and market structure, which indicates that the market maturity level is primarily led by market efficiency, while market scale and market structure play complementary roles.

Shenzhen and Beijing. According to the scores obtained from the maturity model, the pilot carbon markets in Shenzhen and Beijing are in the medium maturity stage and rank first among all pilot zones. Shenzhen and Beijing have the best performances in market efficiency and market structure, making them the leading markets among the others. In the medium maturity stage, the maturity level of the market is growing with accumulated experiences. An increasing number of firms have realized the function of the carbon market and have begun to learn from it. Notably, there is also increasing trader participation, as well as an increasing market scale. The legislation system of the market is strengthening; the price is becoming independent and stable; and the firms are capable of engaging in a free trade in the market. In the next phase, the Beijing pilot could pay more attention to increasing market scale, especially on increasing the emission coverage and stimulating higher trading volumes. The Shenzhen pilot also needs to increase the emission coverage and also to include more sectors into the market scheme.

Guangdong, Hubei, and Shanghai. The pilot carbon markets in Guangdong, Hubei, and Shanghai are in the stage of maturity, ranking second among all other pilot zones. We noticed that Guangdong and Hubei have the best performances in the aspect of market scale. At their maturity stage, the carbon price is strongly influenced by relevant policies, the market structure and efficiency on the other hand, should be improved. In the subsequent step, Guangdong, Hubei, and Shanghai need to increase the number of participants, while Hubei and Shanghai need to increase the emission coverage.

Tianjin and Chongqing. The pilot carbon markets in Tianjin and Chongqing were ranked last, indicating that they require greater efforts in all the aspects.

3.2. Specific results on the three aspects of the maturity degree

3.2.1. Market scale

It is very important to achieve a certain level of market scale for market maturity. With a large scale, the market could attract several firms to participate in the carbon trading deals. The market scale could also provide numerous opportunities with potential benefits. Among the seven pilots, the population, industry structure, resource endowment, and other factors that would influence the economic development and growth are with great differences, and the market scale of these places are also with disparity. Compared with the other two aspects, the market scales did not perform well enough in all pilot carbon markets. Guangdong and Hubei have a good performance in the market scale. Beijing was at the same level with Shenzhen and ranked second. Similarly, Tianjin and Shanghai were equal and ranked third. Chongqing had the lowest ranking on market scale (Fig. 2).

Looking closer, Guangdong, Beijing and Shanghai have a fair share among the four indicators. The condition for them to further enlarge the market scale is relatively positive. Guangdong's participants number is at a lower level. Beijing's trading

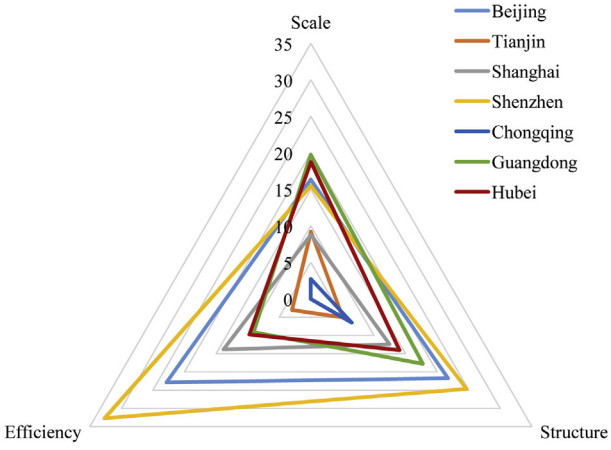

Fig. 1. Maturity degree in the three aspects of China's seven pilot carbon markets.

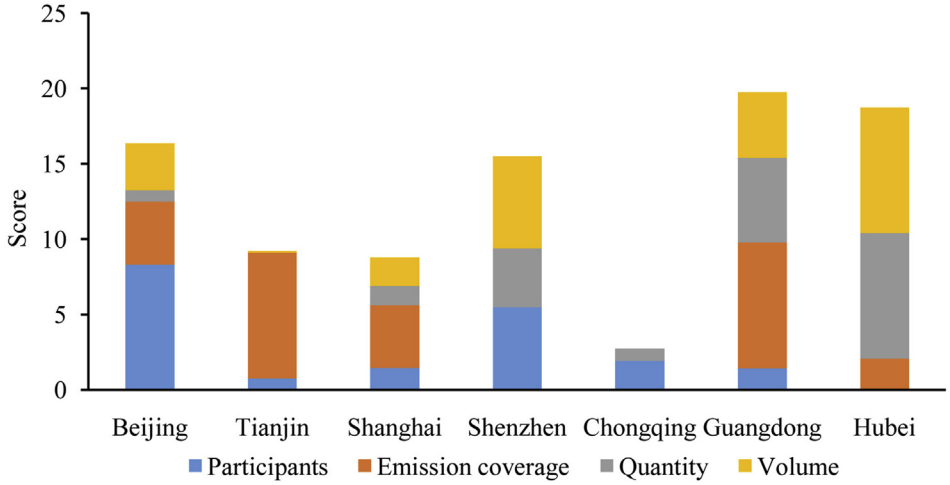

Fig. 2. Results for market scale.

quantity looks uneven comparing to the trading volume. Hubei and Shenzhen have relatively high scores on the dimension of market scale, but they are missing scores on single indicator, where Hubei is short on participants and Shenzhen is short on emission coverage. Tianjin has a relatively high performance on the emission coverage, which makes it get a total score on market scale as high as Shanghai. But Tianjin, as well as Chongqing, has very limited performance on other counterpart indicators.

3.2.2. Market structure

How well the market structure is designed and improved decides the speed and possibility of market's growth to higher maturity. Shenzhen and Beijing have a good performance on the market structure while Guangdong, Hubei, and Shanghai ranked second. Chongqing and Tianjin did not perform well in this aspect (Fig. 3).

Shenzhen has the highest score on market structure among all pilot carbon markets. However, Shenzhen still has the lowest score on the indicator of industry coverage. Beijing has medium performance on all four indicators under market structure, which makes it ranking the second high among all the pilots on market structure. Guangdong, Hubei and Shanghai rank the middle on market structure. They all have lower performance on firm size, which means the firms included into the carbon market need to be enlarged. Chongqing and Tianjin have the lowest performances on market structure, with the lowest performances on legislation level. Tianjin also performs the lowest on third party participation.

3.2.3. Market efficiency

Shenzhen recorded the best performance on market efficiency. Beijing, Shanghai, Guangdong, and Hubei were in the middle position in market efficiency performance while Tianjin and Chongqing were at the bottom of this dimension (Fig. 4).

Shenzhen has performance on all four indicators under market efficiency, including price level, valid trading days, price effectiveness, and complexity of products. Beijing ranks second on market efficiency, with good performance on price

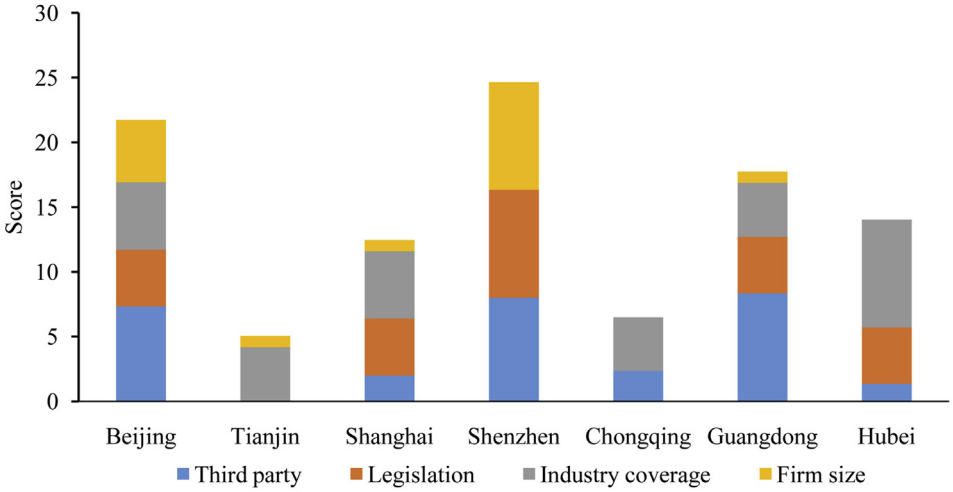

Fig. 3. Results for market structure.

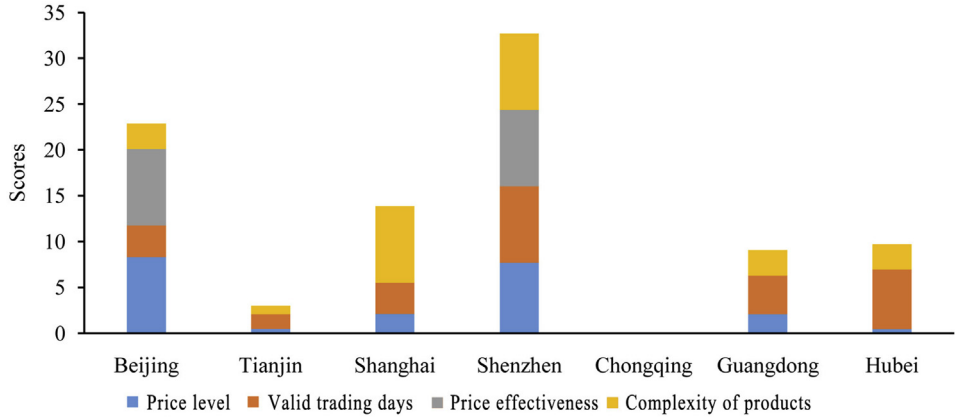

Fig. 4. Results for market efficiency.

level and price efficiency. Despite of the two pilots above, all rest pilots failed to perform well on price effectiveness. Chongqing has lowest performance in all four indicators under market efficiency, with low price level, smallest valid trading days, limited products.

4. Conclusion and discussion

4.1. Conclusion

There is significant disparity in the scores that the pilot carbon markets got. According to this study, Shenzhen and Beijing have better performances among the pilot markets, and Chongqing and Tianjin have much lower performances. None of the seven pilot markets has stepped into the mature stage.

The drivers to maintain market scale is different among the pilot markets. At the pilot stage, single or limited indicators can drive the score of market scale to certain degree. There are great potential for the pilot markets in Chongqing, Tianjin and Shanghai to grow.

The pilots who get higher scores on market structure normally perform well on the four indicators, including third party participation, legislation level, industry coverage, and firm size. Further downscale the firm size could contribute to a better market structure in most pilots. There are still some low-hanging fruits for the pilot markets to enhance their market structure. Chongqing and Tianjin could improve their market structure through raising the legislation level. Hubei and Tianjin need to increase the participation of the third party entities.

The performance of market efficiency is well-distributed. Shenzhen and Beijing perform the best among the pilot markets, and only they two have effective prices. Most of the pilot markets failed to perform well on price efficiency. Chongqing performs the lowest on the dimension of market efficiency and all the four indicators, including price level, price effectiveness, valid trading days, and complexity of products.

4.2. Discussion

The results of this study show that none of the seven pilot carbon markets has obtained a maturity degree score higher than 80, indicating that no mature pilot market has developed in China. This could echo the result from Zhang et al. (2016), in which the integration level of the seven pilot carbon markets was not sufficiently high for a unified national market, with a visionary data. At this maturity level of the markets, there are plenty work to do to raise the scores. Each pilot could make certain this according to the indicators where they perform low to improve the market maturity level.

The result and conclusion could be compared with previous studies, and the essence of this study is that it makes a comparison among seven pilot markets, and makes a map of the maturity level distribution of them. Shenzhen and Beijing get the high scores in general, which echoes the previous research on market liquidity (Cong and Lo, 2017; Hu et al., 2017; Shen and Lin, 2017), with broader views to see how the market scale and market structure of Shenzhen and Beijing were formalized. This study gets the conclusion that most of the pilots fail to perform on price efficiency which also go in line with previous researches (Cong and Lo, 2017; Ibikunle et al., 2016), and with a clear ranking of the pilots. Shen and Lin (2017) showed that owing to a stable performance of the carbon price and large market scale, Hubei is predicted to be the future center of the expected national carbon market. This study shows that the competitiveness of the Hubei pilot market in terms of market scale was not strongly sufficient to categorize it as the leading market. Meanwhile, we noticed that in Hubei, the participants indicator obtained the lowest score, indicating that Hubei still have much to improve in the market scale.

This study also discusses several methods to accomplish a successful carbon pricing target. It is suggested that considerable regulatory attention and economic fixes are needed to improve market efficiency and eliminate sources of market distortions (Cong and Lo, 2017). We noticed that the legislative level performances of different pilot markets lead to different scores in market structure, which helps the pilot market to get a higher score and show a specific way to improve the regulatory. Third parties could facilitate information exchanges to reduce the level of asymmetry (Bobekova, 2015), or provide innovation. This study showed that Beijing, Shenzhen, and Guangdong apparently have active

third party entities in the pilot carbon markets, making them get higher total scores of their maturity degree performance. The expertise in carbon trading in China's third party entities should also be improved.

Conflict of interest

The authors declare no conflict of interest.

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