Carbon Trading Scheme in China: Evaluating Performance of the Seven Pilot Projects

Draft paper by

Xing CHEN
xingc@pku.edu.cn
PhD Candidate, College of Environmental Science and Engineering, Peking University, Beijing, 100871, China

Jintao XU
xujt@nsd.pku.edu.cn
Professor, National School of Development, Peking University, Beijing, 100871, China

Abstract: Establishing a carbon emission permit trading system (ETS) gives China a useful tool to realize its Paris commitment**.** Since 2014, seven pilot sites were established to test validity and also generate lessons of the ETS system. Based on assessment of the pilots, the Central Government was ready to announce full-fledged implementation of ETS in whole China in late 2017. In this paper we try to provide an independent assessment of the seven pilot projects, including policy design, monitoring and measurement issues, and comparative performance against the premises established for the pilots and the future ETS system. Synthetic control method was used to evaluate effects of the pilots in carbon emission reduction. Our findings are that success has been limited and uneven across the pilots, which warrants deeper evaluation of the difference across the pilots and caution in scheme expansion. Results from the analyses shed lights for policy improvement in the nationwide scheme development.

Key words: emission trading system; EU ETS; synthetic control

1 Introduction

Addressing climate change and reducing greenhouse gas emission has become the consensus of the world's major countries. Policy makers are employing or contemplating the use of market-based instruments for climate policy. In recent years, cap and trade scheme in carbon emission permits has commanded most of the attention in discussions relating to climate change. A main theoretical attraction of Cap-and-trade is its potential to achieve emissions reductions at low cost than conventional, direct regulations such as mandated technologies or performance standards.

In October 2011, the National Development Commission (NDRC) designated

seven provinces and cities—Beijing, Chongqing, Guangdong, Shanghai, Shenzhen, Tianjin and Hubei–as regional mandatory ETS pilots. Chinese government explicitly proposed to build their own nation-wide carbon emissions trading market by the end of 2017. While there is wide agreement among economists as to the potential advantages of market-based instruments, there is much debate as to whether cap-and-trade is the best policy option for China.

This article provides an overview and analysis of China carbon market after 3 years in operation. A background and design elements of the emissions trading scheme are introduced, along with comparison between 7 pilots in China. We use synthetic control method to evaluate compliance performance in regional level, and sector level in following work. Challenges existed in China carbon market are identified and policy recommendations to further improve the China carbon market are also provided.

The rest of this paper is organized as follows. The next section lays out the legislation of China cap-and-trade systems, and analyzes existing conventional forms of regulation. Section 3 then focuses on the actual implementation and market performance of seven pilots. Section 4 introduces the evaluation of emission reduction achievements of seven pilots based on synthetic control method. The final section provides highlights of key conclusions from the analyses, main challenges and policy recommendations for the program to go nationwide.

2 Policy Overview

Theoretically, cap-and-trade scheme affects the total greenhouse gas emission by creating a market for emission permits allocated to individual emitters under an aggregate emission cap. The regulatory authority stipulates the total allowable quantity of emission (the cap), in doing so the level of scarcity of allowable greenhouse gas emissions is determined; total allowable emission then is divided into a certain number of emission permits which are allocated to individual emitters based upon certain rules. Recognizing difference in marginal cost of implementing the permits by different individual emitters, trading of permits is allowed and equilibrium price of the permits emerges. This equilibrium price provides a signal of the level of scarcity of the emission permits and can guide individual emitters (firms most likely) to choose between reducing GHG emission or increasing GHG emission, and technologies corresponding to their choices. Moreover, an effective cap-and-trade scheme achieves the set cap with minimum social cost.

Generally, an emitting source will buy additional permits if the market price of permits is less than what it would cost the emitter, at the margin, to bring emissions down to the level implied by its initial permit holding. Likewise, an emitter will sell

permits if the price is higher than what it would cost to achieve the additional reductions made necessary by the sale of permits. Every permit purchase by one entity corresponds to an equal reduction in the permit held by the selling entity. Thus, permit trading does not affect total allowable emissions because they do not alter the total number of permits in circulation.

2.1 Legislation Basis

In 2009, China pledged to reduce the intensity of carbon dioxide emissions per unit of GDP in 2020 by 40% to 45% from the level of 2005. On 1st December 2011, China suggested in its "Twelfth Five-Year Plan for the National Economic and Social Development" for the first time to "gradually establish a carbon emission trading market" as a way to control greenhouse gas emissions. The "GHG Emission Control Work Schedule for the 12th Five-Year" specifically pointed out "to carry out carbon emission trading pilot" and "to develop China's overall program for carbon trading market." This indicates that China's carbon trading policy will follow the principle of "first pilot at local level, then scale-up". In October 2011, "Notice on Conducting Carbon Trading Pilots" by NDRC confirmed the first 7 designated pilots. The pilot provinces and cities established institutional basis for carbon trading and officially launched trading during 2013-2014. On the basis of the pilot experience, China will accelerate the construction of the national carbon trading market and strive to put it in operation in the end of 2017.

The legal basis of the policy is an important prerequisite for the successful implementation of the policy. In order to create the companies' demand for emission permits and to stimulate their enthusiasm and confidence to participate in the carbon market, it is important that the government administrative departments can legally impose mandatory punishments in companies that do not comply with reporting, trading or compliance rules. Therefore, legal documents that give administrative departments the legitimacy to impose punishments are a key component of establishing an emission trading scheme. Legal authorities listed in Table 1 have different weights in effectiveness - some are resolution passed by the local People's Congress Standing Committee, while others are government orders. In addition to legal tools, some pilot also used administrative methods such as confiscation of the next year permits, as well as public shaming to promote enterprises' compliance efforts.

Tab.1 Legislation of the Carbon Trading Pilots

Region	Legal Documents
Beijing	"Beijing Municipal People's Congress Standing Committee - Resolution on Beijing to Carry out Carbon Trade Pilot under the Premise of Strictly Controlling Total Carbon Emissions"

Shanghai	"Shanghai Carbon Emission Management Interim Guidelines" (Shanghai Municipal People's Government Order No. 10, November 18, 2013)
Guangdong	"Guangdong Province Carbon Emission Management Interim Guidelines" (Guangdong Provincial People's Government Order No. 197, January 15, 2014)
Shenzhen	"Regulation on Carbon Emission Management for the Shenzhen Special Economic Zone" (approved by the Shenzhen Municipal People's Congress on December 30, 2012)
Tianjin	"General Office of Tianjin Municipal People's Government – Notice on Issuing the Interim Measures on Carbon Emission Trade in Tianjin"
Hubei	"Hubei Province Carbon Emission and Trade Management Interim Measures" (Hubei Provincial Government Order 371, April 23, 2014)
Chongqing	"Chongqing Carbon Emission and Trade Management Interim Measures" (approved by the Chongqing Municipal People's Government 41st Executive Meeting on March 27, 2014)

2.2 Operating mechanism

China embarks on building a carbon trading market from scratch to reduce greenhouse gas emissions. The science, rationality and effectiveness associated with the system design are critical for the success of the pilot and of the future national carbon market. In addition to learning from existing markets including the European emission trade scheme (EU ETS) and the Regional Greenhouse Gas Initiative (RGGI) in the United States, China also studies its actuality in-depth and established a locally appropriate market. Overall, carbon trading policy in China's seven pilots has the following characteristics:

− Executive entity: mostly local Development and Reform Commission, mainly by its department in charge of resource, environment and energy. Local finance bureaus and other departments provide support to the implementation.

− Industries regulated: basically all energy intensive industries are covered including electricity, steel, cement, chemicals in the pilot trading scheme. Beijing, Shanghai and Tianjin also included building and service industry.

− Emission scope covered: Most pilots cover both direct and indirect emissions, but there are some differences in the specific definition of indirect emissions - some only account for the consumption of purchased electricity, while others cover consumption of purchased electricity and heat. Hubei trades direct emissions only.

− Government intervention: government intervention on the carbon market includes mostly emission data collection, emission permit allocation and auction, and

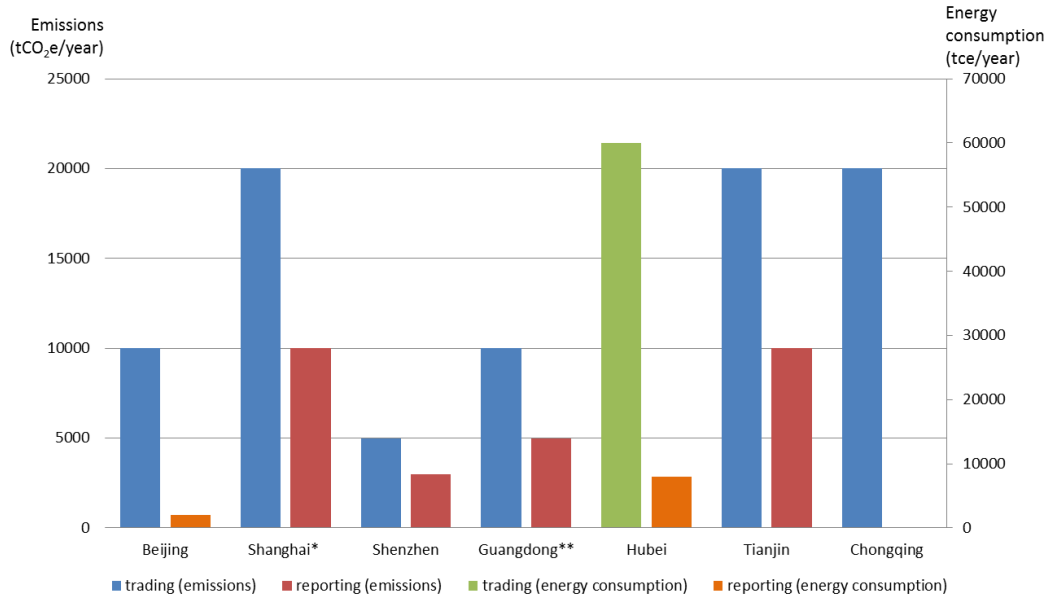
intervention on market price when necessary. For example, Beijing, Shanghai and Shenzhen clearly put forward market conditions and methodologies to regulate prices for emission permits

－Permit allocation methodology: all pilots adopted the historical emission method to allocate permits, while benchmarking method is used for new facilities or certain industries. Guangdong, Shenzhen and Hubei conducted auction for emissions permit allocation. Other pilots generally distributed permits free of charge.

－Regulation on the use of carbon emission reduction credits: all pilots recognize China Certified Emission Reductions (CCER) approved by NDRC or other types of emission reduction credits other administrative authorities for trading. Yet certain regulations are made for ceiling amount and conditions for usage. For example, Beijing and Guangdong required respectively that 50% and 70% of carbon reduction credits are generated locally in the region.

－Transaction Threshold and Reporting Threshold: The pilots also set market access conditions for companies involved in the trading scheme and announced thresholds of emissions reporting for other large emitters that haven't yet been covered by the trading system (referred as "reporting companies"). The reporting companies need to report their annual emissions to the government every year so the latter could determine whether they should be included in the future carbon trading scheme or not. The emissions of companies involved in carbon trading (referred as "emission control companies") account for about 60% of total regional emissions in Guangdong and Tianjin, and for more than 40% in other pilot regions.

Fig.1 "Transaction Threshold" and "Reporting Threshold" in Seven Pilots



3 Implementation and Market transaction

The effectiveness of emission trading pilots relies not only on institutional design but also on the actualities in policy implementation. Table 2 lists indicators associated with performance of the carbon trading policy. Overall, in the existing system design, all procedures for the carbon trading including permit distribution, emission data collection, punishment enforcement and issuance of certified carbon emission reduction credits have been completed successfully, although there are flaws in the system.

Tab.2 Implementation of China Seven Carbon Emission Trading Pilot

Activity				
Licensing, permitting and procurement function	Indicator	Responsible Institution	Data Source	Status
Allocate permits to companies from time to time	Total amount of permits allocated by the government	Local Development and Reform Commission (DRC)	Local DRC Website	The ETS pilots allocated 2013 and 2014 emission permits on time (about respectively 730 million tons and 1285 million tons in total)
Information collection and tracking function	Indicator	Responsible Institution	Data Source	Status
Collect emission control companies' emission reports and third-party verification reports based on accounting and reporting rules	Number of emission reports and verification reports collected	Local DRC	Local DRC Website, Interviews with ETS staff	Collected emission reports and third-party verification reports from 1736 emission control companies in the five pilots that came to operation in 2013 (including 197 buildings in Shenzhen)[①]
Conduct sample checks on third-party verification reports	Number of verification reports checked	Local DRC	Local DRC Website, Interviews with ETS staff	No data found on sample check for verification reports
Collect and disclose information on	Whether regularly publish	Local DRC, carbon trading exchanges	Carbon trading exchanges	All carbon trading exchanges released complete information on

[①] 415 companies in Beijing, 191 in Shanghai, 184 in Guangdong, 114 in Tianjin, and 635 companies and 197 buildings in Shenzhen

trading volume and price	reports on trade volume and price	in each pilot region	in each pilot region Website carbon K-line website	trading volume and price except the one in Guangdong, which only announces data of the most recent trades
Collect and disclose information on the overall compliance	Whether timely announce the compliance rate	Local DRC	Local DRC Website	All pilots published reports on compliance of the previous year within 3 months after compliance cycle closure (Sino-Carbon Innovation and Investment Co. 2015)
Compliance and enforcement function	Indicator	Responsible Institution	Data Source	Status
Impose punishments on non-compliance companies for reporting or permit surrendering according to rules	Number of companies that are imposed with punishment	Local DRC	Local DRC Website, news report	14 companies were imposed punishment due to noncompliance. No data found on what kind of penalty was given.
Other policy administration activities	Indicator	Responsible Institution	Data Source	Status
Issue China Certified Emission Reduction (CCER)	Total CCER issued	Dept. of Climate Change in National Development and Reform Commission (NDRC)	China Certified Emission Reduction Exchange Info-Platform	As of January 14, 2015, a total of 13.72 million tons CCER has been issued
Intermediate effects				
Effects on behavior, technology and practice	Indicator	Responsible Institution	Data Source	Status
Emission control companies use carbon trading to adjust their operation and comply with requirements	Amount of emission permit traded	Carbon trading exchanges in each pilot region	Carbon trading exchanges in each pilot region	By June 30, 2017, a total of 114.58 million tons permits was traded
Emission control companies fulfill their compliance obligation through operation and production	Compliance rate (percentage of companies that surrendering sufficient	Local DRC	Local DRC Website	Compliance rates for the 7 pilots in 2013 were: Beijing 97.1%, Shanghai 100%, Guangdong 98.9%, Shenzhen 99.4% and Tianjin 96.5%

adjustment	permits in time)			

Summarize based on Local DRC website of Beijing, Shanghai, Shenzhen, Tianjin, Chongqing, Guangdong, Hubei.

Timely emission permit allocation is a necessary prerequisite for the carbon market to operate. Each pilot established its carbon emission registration e-platform to enable timely allocation of the 2013 and 2014 permits. Information on permit allocation was also announced at local DRC website. Guangdong, Shenzhen and Hubei conducted auction for emission permits. It should be noted that disclosure of data of government-allocated emission permits needs to be improved. For example, the Beijing Municipal Commission of Development and Reform did not formally disclose the exact data of its emission permits allocated in 2013 and 2014.

Accuracy and transparency of emissions data is an important basis for carbon trading. The role of the government is to collect and track data on corporate-level emissions, market-wide carbon trading and overall compliance situation. Currently, all governments in pilot regions require emission control companies to submit their emission reports and third-party verification report. In 2013, five pilot regions officially started launched the trading, and collected reports from 1736 emission control companies (including some building owners). Third-party verification report is required to be issued by the agency designated by the government to ensure the accuracy of emission data. Administrative authorities also regularly sample check the verification reports as an additional data quality control method. However, the pilot did not announce any information on the random checks of verification reports and, therefore, the effect of this mechanism and the quality of these verification reports has to be further investigated. Announcement on transactions and compliance are mainly published on local DRC's website. All carbon trading exchanges released complete information on trade volume and price. All pilots published reports on compliance of the previous year within 3 months after closure of the 2013 compliance cycle. Information on market transactions and compliance is rather transparent.

Strict regulation and enforcement can encourage companies to pay attention to carbon emission limits and to actively participate in carbon trading. Pilot regions set different rules of punishments on companies failing to report or surrender permits according to the rules, including fines and urges for compliance. Later in 2013, Beijing and Guangdong imposed punishment respectively to 12 and 2 companies that failed to perform their obligations in time but did not release any data on what kind of penalty was given. Shenzhen urged 4 companies failing to surrender permits in time to complete their compliance operation before the extended deadline without giving penalty. Tianjin had 4 companies fail to perform the 2013 annual obligation in time but its Interim Measures did not include any penalty clause such as fines or deducting from future quota. Beijing and Guangdong are the most stringent with enforcement for non-compliance, while Shenzhen provides a certain grace period to urge companies to correct their non-compliance behavior. Enforcement in Tianjin is the

weakest as no clear rules were set for penalties, resulting in lax attention or respect for carbon emission quota. It should be noted that there was no non-compliance in Shanghai in 2013, as when deadline was approaching (June 30) Shanghai DRC auctioned 580,000 tons emission permits that companies could buy and use for compliance – this is also a way to increase compliance rate. Overall, pilot regions mostly take the form of fines and other penalties to enforce carbon trade policies, while their actual enforcement strength varies. Some pilot region assisted companies to comply through granting grace period or auctioning additional permits. Enforcement could be weak when there were no punishment rules set, as in the case of Tianjin.

Intermediate effects of the carbon trading policy may be seen in participation of the emission control companies in the market. This study selected three indicators – active ratio, trading volume, and trading turnover to evaluate the intermediate effects of the carbon trading policy.

Tab.3 Trading indicators of seven pilots in China

Pilots	Starting date	Total trading days	Active ratio	Average price	Average trading volume	Average trading turnover	Share of total volume
Shenzhen	19-Jun-13	1003	90%	47	18604	612295	16%
Beijing	28-Nov-13	891	69%	50	7869	396690	6%
Shanghai	19-Dec-13	876	63%	25	11819	251740	9%
Guangdong	19-Dec-13	876	71%	26	34399	508819	26%
Tianjin	26-Dec-13	871	52%	22	3450	47261	3%
Hubei	2-Apr-14	806	96%	21	50163	988459	35%
Chongqing	16-Jun-14	752	18%	20	6644	30968	5%
Average		868	66%	30	18992	405176	-

Note: Active rate = number of days that have trading volume/ Total trading days

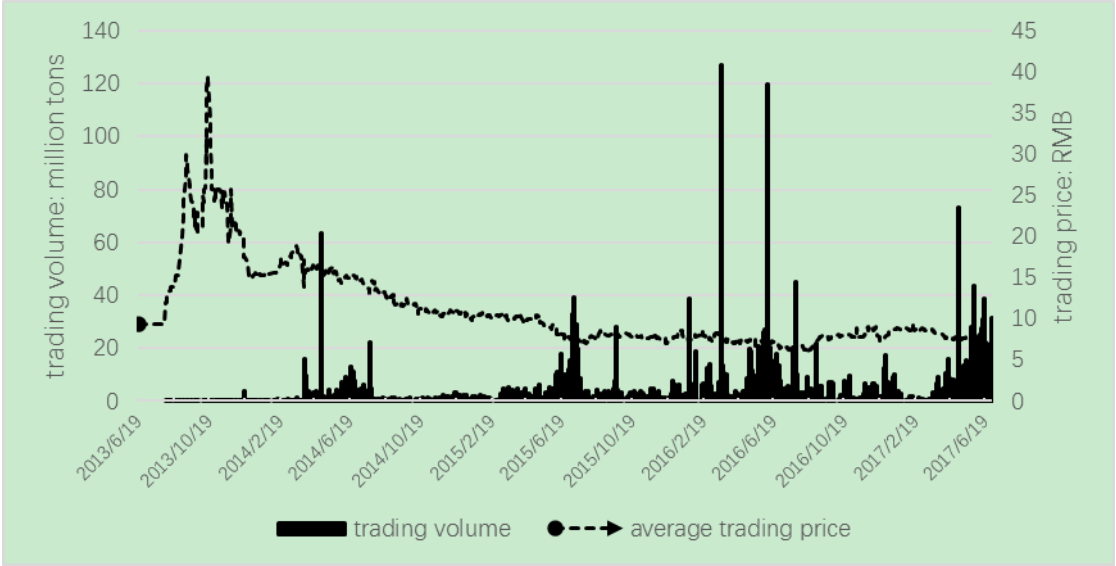
Data soure: http://k.tanjiaoyi.com/

Comparing compliance situation across the piloting regions, from its starting date to the ending date of the trading period, reveals that Hubei, Guangdong and Shenzhen ETS have more active trading than other pilots. From the perspective of secondary market performance, the design and operation of Hubei ETS is successful. Carbon trading is relatively active in Hubei: by June 30, 2017, Hubei ETS has sold 40.48 million tons of permits, with a turnover of 797.82 million Yuan. A complete price curve of carbon market is formed, with a minimum price of 28 Yuan and maximum price of 143 Yuan. By June 30, 2017, trading volume of seven carbon trading pilots

reached 114.58 million tons. According to this study, among the seven pilots Beijing had the highest average price for emission permit - about 50 yuan/ton, followed by Shenzhen with 47 yuan/ton. The price for Shanghai, Chongqing, Hubei and Tianjin were approximately 20-25 yuan/ton. The active rate, average daily trading volume and turnover for Hubei all rank first among seven pilots. At the same time, Tianjin and Chongqing seems to be far behind the average level, reflected by fairly low market liquidity in the two places.

The low liquidity seems to be a big challenge for China's carbon market. In comparison, California carbon market had total of 62495 million tons of emission permit within one year compliance (from Jan 7th 2015 to Dec 24th 2015), and on a single day on January 21, 2015, trading volume surged to 10 million tons, the equivalent of 2/3 of China's total trading volume in all seven pilots[①]. Although the overall size of China's seven pilot carbon markets is substantial, companies were not enthusiastic in participating in carbon trading. It is mainly because of policy uncertainty after the trial period that most companies stayed cautious. In addition, emission control companies are often pressured by other existing energy conservation policy (e.g. key energy users need to complete their assigned energy saving targets) when carbon trade policy could no longer substantially influence corporate behavior. In addition, trading occurred the most around June when the compliance deadline was approaching.

Fig.2 Historical Trend of Emission Permit Trading in the 7 Pilot Regions



① Source: http://calcarbondash.org/

4 Emission Reduction Achievements

4.1 Method and Data

To estimate the effects of events or policy interventions that take place at aggregate level, researchers often use comparative case studies. In comparative case studies, researchers estimate the evolution of aggregate outcome (in this case, carbon dioxide emission) for a unit affected by a particular occurrence of the event and compare it to the evolution of the same aggregates estimated for some control group of unaffected units. However, it is difficult to estimate the emission reduction achievement of carbon trading because of the lack of solid control groups in this case.

Synthetic control method is used for effect estimation in settings where a single unit (a state, country, firm, etc.) is exposed to an event or intervention. The synthetic control method was firstly introduced and implemented in Abadie et al (2003) and Abadie et al (2011). Other comparative study includes investigating the economic impact of German reunification (Abadie 2015) and local impacts of nuclear power facilities (Ando M.,2015). There are also a series of research focusing on China. Liu and Fan (2013) examines the economic impact of China's house property tax pilot based on Chongqing Pilot, and Zhang et al (2016) uses this method to answer the question that "Did Olympic Games improve air quality in Beijing".

Our outcome variable of interest is annual CO2 emission, calculated based on energy consumption at the provincial level. We use annual provincial-level data of energy consumption during the period 1995-2015 from Provincial statistical yearbook. Since seven carbon trading pilots officially went into effect one by one from late 2013, we mark 2013 as treated year. This gives us 17 years of pre-intervention data. Our sample period begins in 1995 because it is the first year for which data on energy consumption are available for all our control provinces. It ends in 2015 because newer data has not been published yet. Based on method proposed by IPCC, we calculate annual CO2 emission level for all provinces.

Take Hubei for an example. We construct the synthetic Hubei as a weighted average of potential control provinces, with weights chosen so that the resulting synthetic Hubei best reproduces the values of a set of predictors of CO2 emission in Hubei before the carbon trading system. Because the synthetic Hubei is meant to reproduce the CO2 emission that would have been observed for Hubei in the absence of carbon trading pilot, we discard from the donor pool provinces that adopted carbon trading system during out sample period. Therefore Beijing, Guangdong, Shanghai, Tianjin, Chongqing are excluded from the donor pool. Finally, our donor pool includes the remaining 24 provinces.

Using the techniques described above, we construct a synthetic for each of Hubei, Guangdong, Tianjin, Shanghai, Beijing, Chongqing that mirrors the values of the

predictors of CO2 emission for themselves before the introduction of carbon trading system. We estimate the emission reduction effect of carbon trading pilots as the difference in CO2 emission between Hubei pilot and its synthetic versions after 2013. We then perform a series of placebo studies that confirm out estimated effects for carbon trading pilots are unusually large relative to the distribution of the estimate that we obtain when we apply the same analysis to the provinces in the donor pool. Then we repeat the work for Beijing, Shanghai, Tianjin, Chongqing, and Guangdong.

4.2 Results

As explained above, we construct the synthetic Hubei as the convex combination of provinces in the donor pool that most closely resembled Hubei in terms of pre-pilot values of CO2 emission predictors. The results are displayed in table 1, which compares the pretreatment characteristics of the actual Hubei with that of the synthetic Hubei, as well as other five pilots.

Tab.4 The society and economy characteristics of actual and synthetic seven pilot

	HB_real	*HB_syn*	*BJ_real*	*BJ_syn*	*SH_real*	*SH_syn*	*TJ_real*	*TJ_syn*	*CQ_real*	*CQ_syn*	*GD_real*	*GD_syn*
GDP	7862.2	7887.3	7172.3	5186.2	9186.0	9141.2	4385.7	3414.2	4029.2	4048.1	2348.4	1750.6
GDP_per	13703.1	13746.8	42862.0	17454.5	47094.2	21964.8	37534.3	14944.7	13678.4	13286.3	24596.6	24505.5
Population	5742.4	5759.0	1544.7	2108.6	1848.4	3309.1	1086.8	1979.9	2850.1	2860.6	9033.3	6532.9
Sec_rate	42.6	42.8	29.9	33.5	46.5	50.4	52.8	48.9	44.2	44.3	48.4	49.0

Note: sec_rate refers to the share of second industry in total GDP;

Tab.5 Synthetic weight for each synthetic pilot

Region	*Hubei_weight*	*Beijing_weight*	*Shanghai_weight*	*Tianjin_weight*	*Chongqing_weight*	*Guangdong_weight*
Anhui	0.036	0	0	0	0.027	0
Fujian	0.025	0	0	0	0.03	0
Gansu	0.019	0	0	0	0.047	0
Guangxi	0.033	0	0	0	0.031	0
Guizhou	0.025	0	0	0	0.042	0
Hainan	0.096	0.682	0	0	0.08	0.144
Hebei	0.026	0	0	0	0.02	0
Heilongji	0.018	0	0	0	0.034	0

ang						
Henan	0.045	0	0	0	0.015	0
Hunan	0.059	0	0	0	0.023	0
InnerMo ngolia	0.024	0	0.018	0	0.036	0
Jiangsu	0.057	0	0	0	0.012	0.856
Jiangxi	0.025	0	0	0	0.034	0
Jilin	0.017	0	0	0.566	0.04	0
Liaoning	0.024	0	0	0	0.026	0
Qinghai	0.013	0	0.352	0.381	0.301	0
Shaanxi	0.02	0	0	0	0.036	0
Shandon g	0.027	0	0	0	0.01	0
Shanxi	0.017	0	0	0	0.039	0
Sichuan	0.322	0	0	0	0.02	0
Xinjiang	0.021	0	0	0	0.043	0
Yunnan	0.025	0	0	0	0.036	0
Zhejiang	0.029	0.318	0.629	0.052	0.02	0

Because social and economic characteristics vary substantially across provinces, different synthetic results emerge. Generally, the closer to the average level of whole country, the better synthetic result is. For example, Hubei, Guangdong, Tianjin have a better synthetic result than Shanghai, Beijing and Chongqing.

Figure 6 plots the trends in CO2 emission in Hubei and the synthetic Hubei. As this figure suggests, since 2013, CO2 emission in Hubei and synthetic Hubei differed notably.

Fig.6 CO2 emission between synthetic Hubei and real Hubei

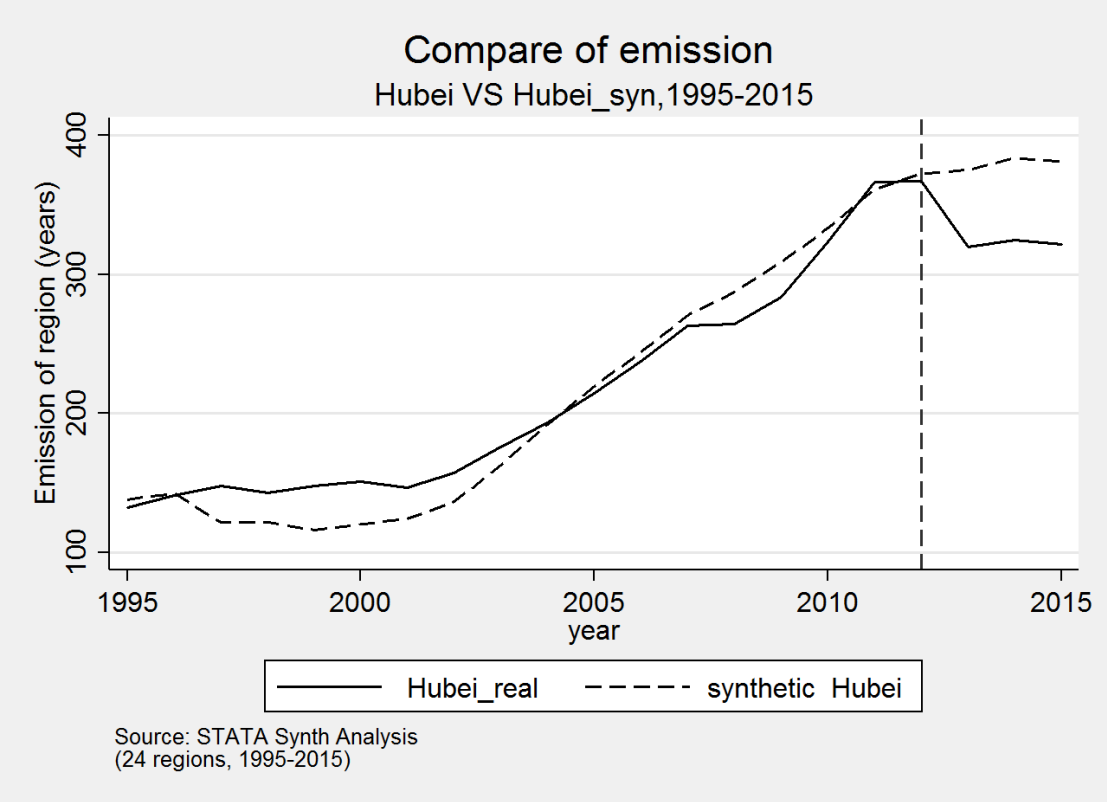
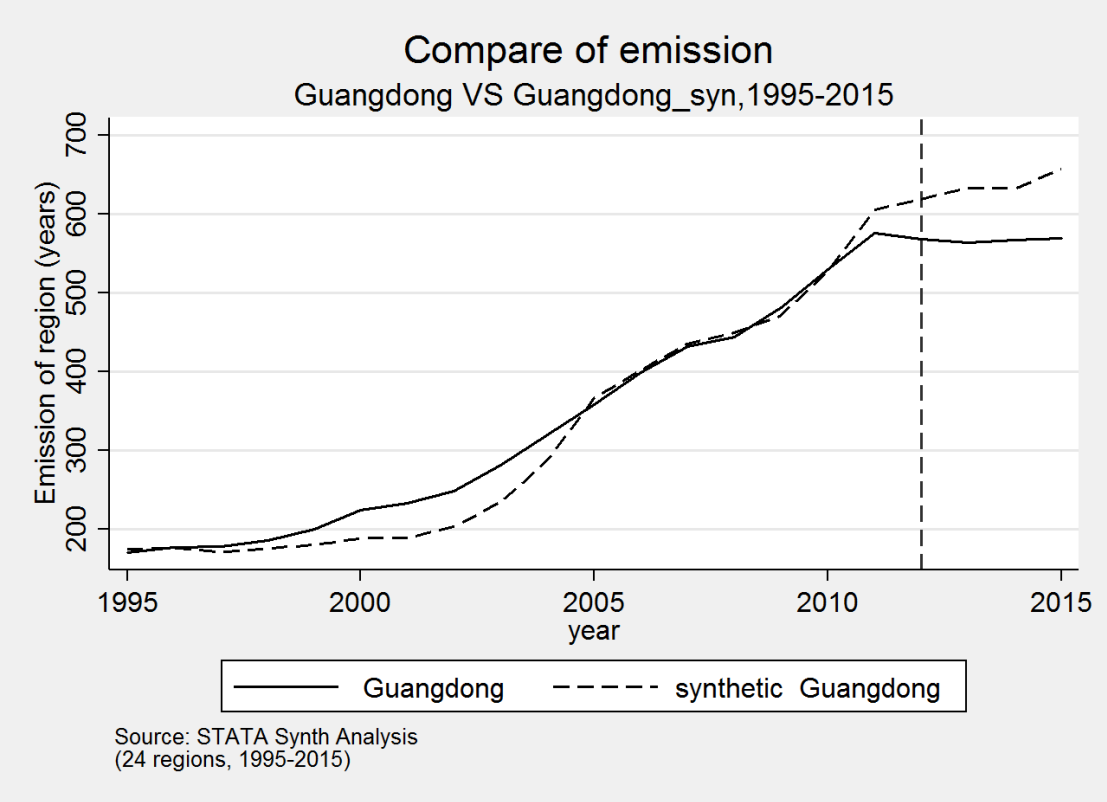


Figure 7 shows that before 2012, the synthetic data fits the actual data quite well for Guangdong. After 2013, the gap between CO2 emission of Guangdong and that of the synthetic Guangdong emerges, which shows a deviation from the synthetic data.

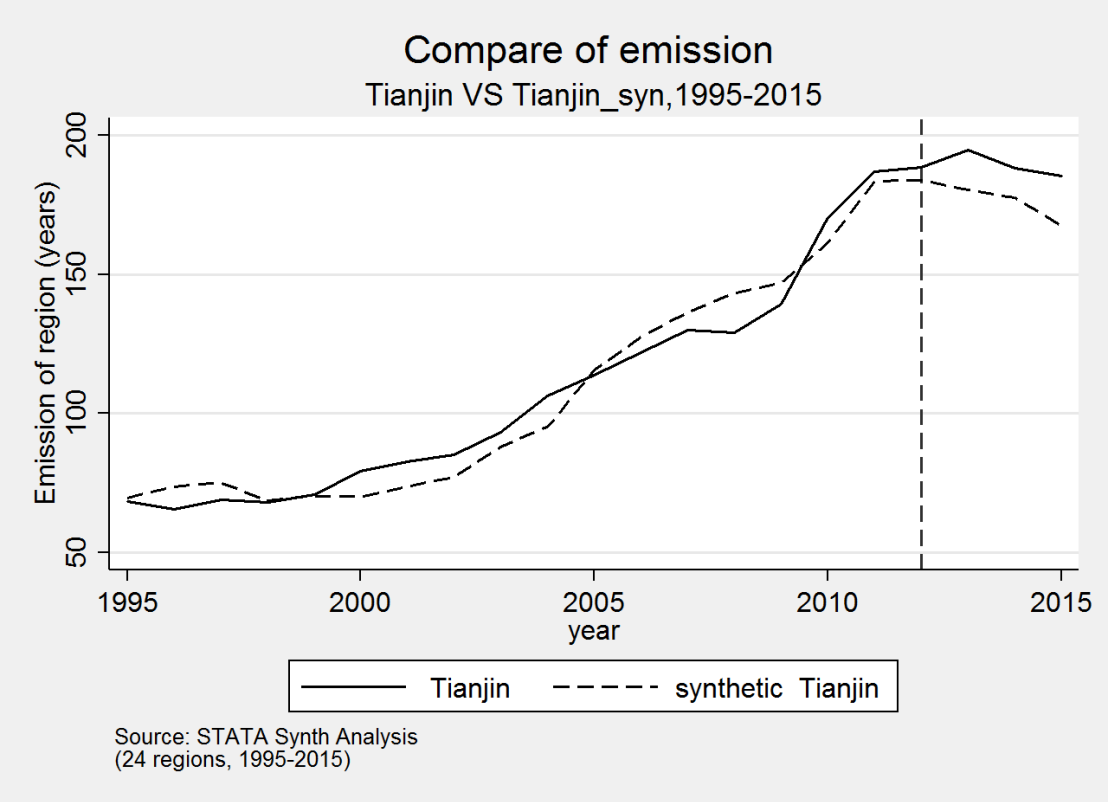
Fig.7 CO2 emission between synthetic Guangdong and real Guangdong



From the perspective of trading indictors, Hubei and Guangdong(including Shenzhen) have more active trading than other 5 pilots. The synthetic results support our expectation: more trading volume results in more emission reduction.

Figure 8 plots the trends in CO2 emission in Tianjin and the synthetic Tianjin. As this figure suggests, since 2013, CO2 emission in Tianjin and synthetic Tianjin did not differed notably. The result can be expected from the low liquidity of Tianjin trading market.

Fig.8 CO2 emission between synthetic Tianjin and real Tianjin



However, we cannot get a good simulation before 2013 for Beijing, Shanghai and Chongqing, their results are attached in Appendix.

4.3 Robustness test

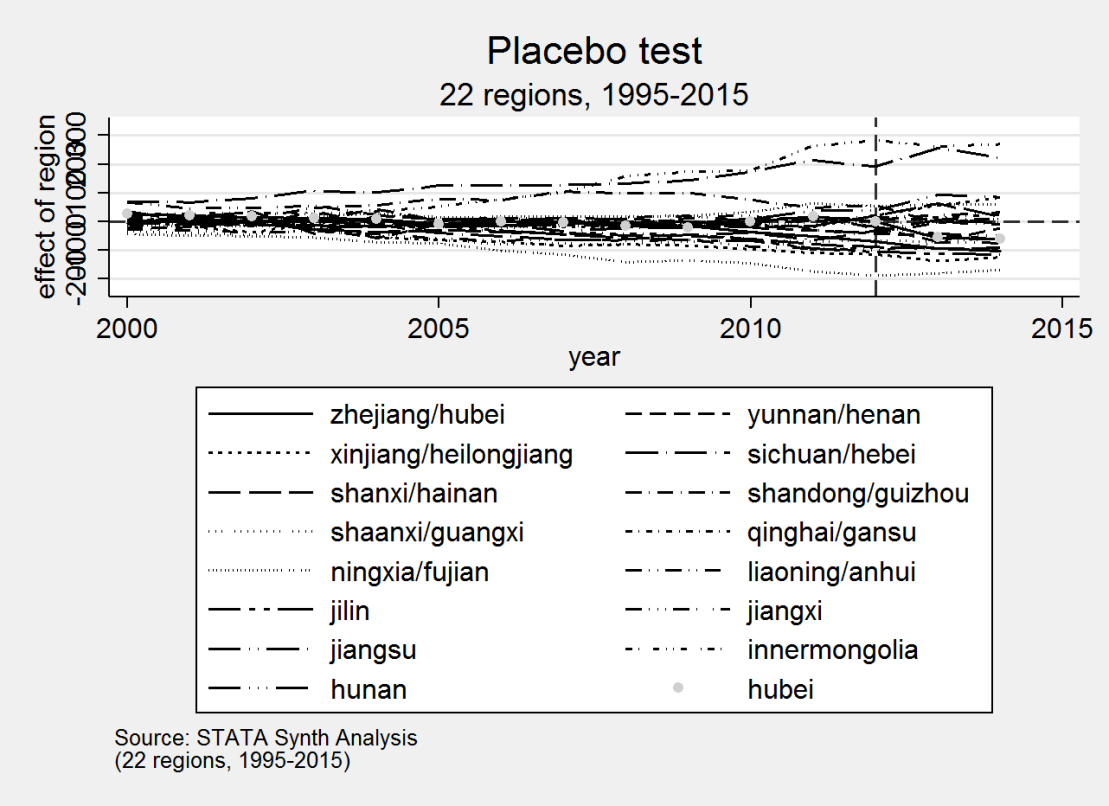
First we will discuss estimation results for Hubei. The previously empirical result reveals a gap between CO2 emission of Hubei and that of synthetic Hubei. The robustness check in this context is permutation test which is similar to rank test in statistics. The purpose is to test the statistical significance of our results.

For example, are there any other provinces among the donor pool shows a gap between CO2 emission and synthetic CO2 emission when these provinces are viewed as treatment group respectively? In other words, what is the probability of appearing the same large gap as Hubei province does? To answer these questions, we iteratively apply the synthetic control method to estimate the impact of carbon trading pilot on every other province. Before doing this test, we need exclude the provinces that do not fit the original data before 2012 well. The gap after the treatment may not be caused by the treatment, but by the bad fitness before the treatment. Therefore, we exclude the provinces whose MSPE before 2012 are larger than 100. Finally, we obtain 22 provinces as potential control groups here.

Figure 9shows the results of permutation test. Each province is viewed as treatment group each time and the gap between CO2 emission and synthetic CO2 emission is drawn respectively.We find that Hubei province is below the zero line, which means

the probability of estimating a gap of the magnitude of the gap for Hubei under a random permutation of the treatment in our data is 1/22. In other words, the previous result is statistically significant at 4.5% or so.

Fig.9 Placebo test for Hubei



5 Discussion

5.1 Main Challenges:

Generally, China carbon trading market is not liquid enough to make market well functioned. The low trading activity in market and unenthusiastic transaction of compliance companies make the volume and value of transaction remained at relatively low level. There are policy restraints (for example, cross- provincial trade is prohibited) on trading platform to make the market more liquid. This reduces the attractiveness of China carbon market to investors, especially the institutional investors.

The awareness of and participation in the carbon market of compliance companies is still relatively low. The high volume in the month before compliance date shows that companies still treat the carbon emissions trading as a means of

compliance rather than an investment approach. Carbon assets are not considered valuable for all companies.

Information disclosure needs more improvement. What information should and how it can be disclosed are tasks to be explored and completed step by step in the future.

Among seven pilots, they have different emission reduction achievement. Among the seven Emission Trading Schemes (ETS) Pilots, Hubei is quite representative of China as a whole in many aspects and its ETS Pilot is also very influential. Based on our synthetic result, Hubei have reduced about 59.47 million tons in 2015 due to the carbon trading scheme. Guangdong and Shenzhen also perform better, and they have reduced 37.06 million tons in 2015. However, Tianjin have not notably reduced their carbon emission.

5.2 Policy recommendations:

Consider expanding the coverage of China ETS. For example, Shenzhen transportation sector took up 27.9% of the total emissions in 2010, and data indicates that buildings cover almost half of the whole carbon dioxide emissions in China; therefore, including the transportation sector and buildings into the system is of great importance.

Develop multiple products. Currently, the single spot product greatly limits the development of the market. It is suggested that the competent authorities should start research on derivative products and apply for the permits from the regulators to become the first carbon futures center.

Improve the market transparency. All pilots should develop and publicize more regulations under Shenzhen ETS Administration Decree to provide more certainty for the market, increase the transparency of the system.

Establish long-term special fund supporting the operation and development of the carbon market to support the infrastructure research and capacity building. Encouraging the companies and research institutes to conduct research on related topics. The fund should lead the low carbon technology development and industrialization to take advantage of the capital market.

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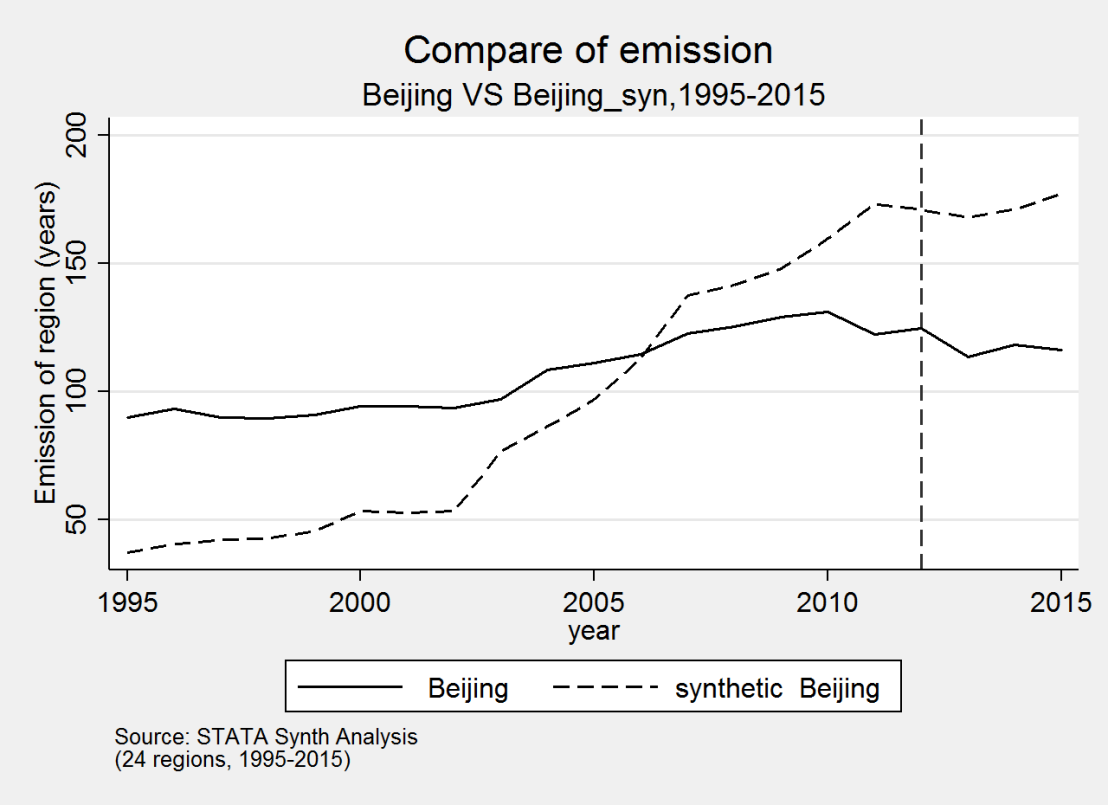
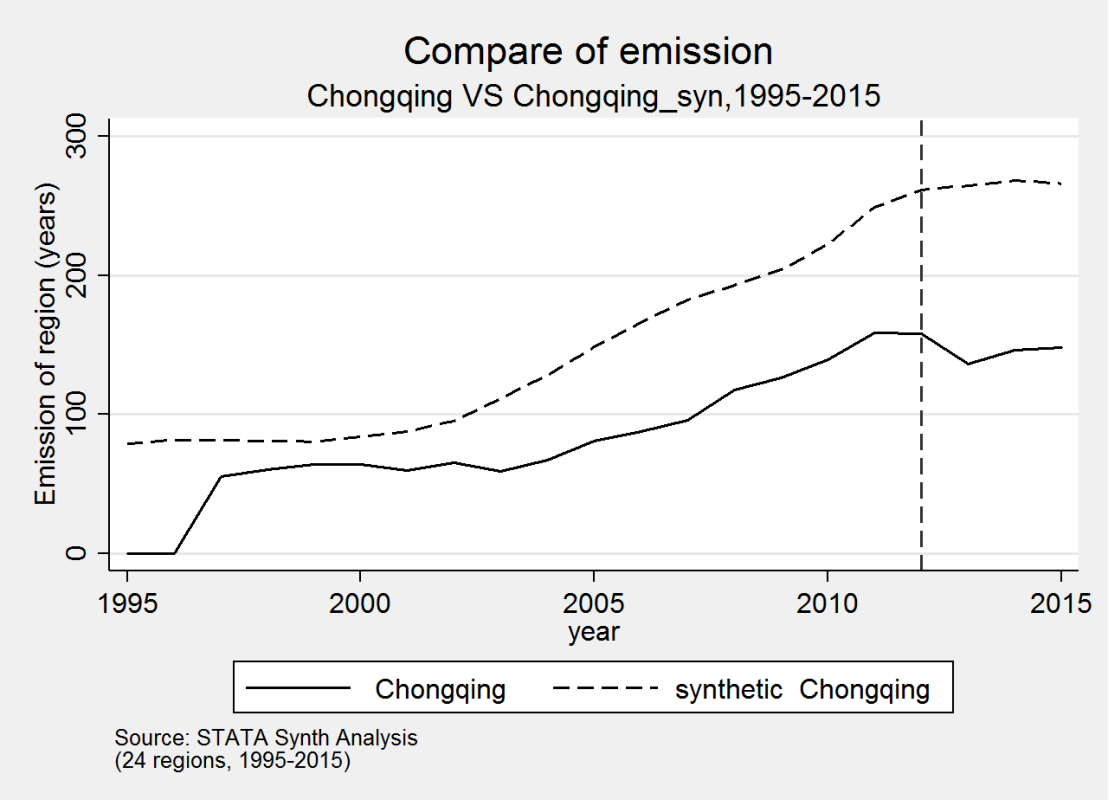
Appendix

Synthetic result for Beijing:



Synthetic result for Chongqing:



Synthetic result for Shanghai: