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Impact of carbon markets on industrial competitiveness: An analysis of selected industries in Beijing

Min Lu[a,*], Hao Xu[a], Xing Wang[b]

[a] School of Statistic and Data Science, Nanjing Audit University, Nanjing 211815, China
[b] Business School Durham University, Durham DH1 3LB, United Kingdom

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Abstract

Although the booming carbon markets provide additional incentives to reduce greenhouse gases, their impacts on the society and economy have attracted increasing attention. Based on 2014–2016 daily carbon market trading price data, this study estimates the direct and indirect carbon emissions cost incurred by Beijing carbon market and explores its impact on industrial competitiveness via an evaluation model. Our results show that the impact of the carbon emissions cost is negligible, and the proportion of the three most affected industries' added values to Beijing's gross domestic product is only 10%, indicating that the economic impact is limited. However, the impact on the production and supply of power, gas and water industry could reach as high as 3.02% in three years. Compared with the European carbon market, the trading price of Beijing's carbon market is relatively low, and the price cap could possibly increase to 100 Yuan per ton. However, each 10-Yuan increment in the carbon price will increase the impact on industry competitiveness by 1.68%. This study provides a scientific basis for exploring the impact of China's carbon market on industry competitiveness and will be of significant value to policy makers.

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Keywords: Carbon market price; Carbon emissions cost; Industrial competitiveness

1. Introduction

China, a major developing country and primary contributor to greenhouse gas emissions, has made a concerted effort to reduce its industrial emissions. Before the Copenhagen Climate Change Conference in 2009, the Chinese government guaranteed to decrease the amount of CO_2 per unit of gross domestic product (or CO_2 emission intensity) by 40%–45% of the 2005 levels by the year 2020. In the latest "Thirteenth Five-Year Plan" issued by the National Development and Reform Commission (NDRC), China declared its goal to further cut down the unit GDP CO_2 emissions by 18% by the end of 2020, with 2015 as the base year. At the beginning of 2012, the NDRC authorized carbon emission trading pilots in seven Chinese cities, such as Beijing, Shanghai, Tianjin,

* Corresponding author.
E-mail address: lumin@nau.edu.cn (M. Lu).

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Guangdong, Shenzhen, Hubei, and Chongqing, aiming to reducing carbon emissions using a market-based policy instrument. In December 2017, the NDRC announced the launch of the unified Chinese carbon emissions trading system (CETS) and the national carbon emissions trading market construction plan for the power generation industry. The implementation of market mechanisms is essential to control carbon emissions and promote green and low-carbon economic development. While the CETS plays an important role in reducing carbon emissions, promoting energy saving and emissions reduction, and optimizing resource allocation, assessing its impact on society and the economy is theoretically and practically significant. A critical issue regarding CETS is the determination of the possible impacts of its implementation on the industrial competitiveness of related industries.

Toward this end, this study investigates the Beijing carbon emissions trading market and explores the impact on industrial competitiveness of 19 industries in Beijing. Understanding the carbon emissions market impact on industry competitiveness in Beijing is crucial to assess and improve the carbon market. Moreover, the research results from this study will be valuable to cities in China and worldwide.

The remainder of the paper is organized as follows: Section 2 presents a literature review; Section 3 provides the measurement of industry competitiveness, data source, and carbon emissions estimation; Section 4 details the empirical results; and Section 5 concludes the paper with policy implications.

2. Literature review

Since the establishment of carbon trading markets, numerous studies have focused on the impact of the carbon market on social and economic development. Scholars generally consider that the carbon trading markets predominately affect energy-related industries, particularly the power industry. In Europe, a long-term cointegration relationship exists among the European Union emissions trading system (EUETS) carbon price, electricity price, and energy price, and the relationship between the carbon price and the electricity price is weak [1]. In the past, the EUETS has significantly impacted the wholesale price of power in Spain, and it was necessary for French and German power companies to impose restrictions when incorporating the EUETS carbon price into their costs. Furthermore, the EU carbon trading system contributed extensively to the French electricity distribution price [2]. The implementation of the China emissions trading system would increase the electricity market price by 12%, and the carbon price fluctuation would incur the electricity price market volatility by 4%. Moreover, the carbon market would also affect the relative cost of power generation companies using various technologies [3]. Li et al. [4] simulated the impact of China's carbon trading system on the coal and oil industry and concluded that the carbon trading system improved the competitiveness of the petroleum industry and reduced the yield of the coal industry.

The impact of the carbon trading system on non-energy industries, particularly the aviation industry, has also attracted the attention of scholars. After EUETS incorporated the aviation industry, the output and macro impact on air transport were negligible and stable with carbon price changes [5]. Moreover, EUETS did not significantly impact the American aviation industry, whose aviation operations continue to develop [6]. In Italy, although EUETS increased the direct costs of airlines, the increment was limited [7]. Furthermore, based on the data obtained from 18 international airlines between 2008 and 2014, Cui et al. [8] studied the impact of EUETS using the data envelopment analysis (DEA) method and found that despite an increase in the airline buffer period, airlines were able to adjust in the long term to meet the requirements of the carbon trading system.

Numerous studies have explored the impact of the carbon trading system on the social economy, with majority focusing exclusively on EUETS. Rogge et al. [9] studied the impact of EUETS on German companies' research and development, deployment, adjustment, and organizational changes and proposed that the carbon trading system lacked rigor and predictability. Moreover, they determined that the impact of EUETS on corporate innovation was negligible and insufficient to provide basic incentives for innovative activities. Furthermore, research has determined that EUETS currently lacks objectivity in efficiency and responsibility, and EU leaders are reluctant to address these issues [10]. EUETS also affects corporate investment decisions. Although most company managers report a higher price than the actual carbon price in their assessments, the expected carbon prices remain too low to provide additional liquidity for new low-carbon investments [11]. However, although EUETS was considered unsuccessful due to over allocation and low carbon prices, initial stockholders held quotas to preserve the value. The negative correlation of low quotas and corporate value would be significant when high-carbon companies or companies with carbon-related costs were not included in the product price [12]; other studies were interested in CETS. In China, water production and supply, mining auxiliary services and other mining industries, electric power production and supply industries were more sensitive to the policy, and the changes in the industry profits were relatively large. Therefore, it was necessary to subsidize sensitive industries to reduce the adverse effects associated with the implementation of carbon emissions trading policies (Yan et al. [13]). Many scholars exploited the general equilibrium model to study the impact of China's carbon trading pilots on economic development. They found that the Tianjin carbon trading system significantly reduced emissions, with a limited negative impact (Liu et al. [14]). The Guangdong carbon emission trading system reduced SO_2 and NO_x emissions by 12.4% and 11.7%, respectively, in 2020 [15].

All these studies examined the impact of the carbon emission trading system on energy and non-energy industries, as well as the social economy. However, to our best knowledge, few studies have explored the carbon trading system impact on industry competitiveness. In Germany, the German Federal Environmental Agency research report first presented the impact of the EU carbon trading system on the competitiveness of different industries in Germany by establishing an industry competitiveness evaluation model [16]. Based on the Cournot duopoly model theory, this study analyzed the impact of China's carbon trading system on coal and petroleum industries and determined that CETS improved the petroleum industry competitiveness and reduced the coal yield [15]. However, only coal and petroleum industries were selected for analysis in this study, and it focused on constructing theoretical models and simulated results. Empirical research on the competitiveness of different industries based on CETS transaction data has not yet been conducted.

The improvement of industry competitiveness plays a vital role in Beijing's full implementation of the capital city's strategic position and the process of transforming and upgrading industrial structures. Therefore, analyzing the impact of the carbon trading system on the competitiveness of various industries in Beijing and proposing policy propositions for the development of the carbon market will assist with further development of the Beijing carbon market and promote capital sustainable development.

Our research makes three primary contributions to the study of the impact of CETS on industrial competitiveness. Firstly, we extended the research on industrial competitiveness to all industries in one city. We performed a detailed investigation of the carbon emissions costs of 19 industries in Beijing and analyzed their impact on industrial competitiveness. Secondly, we included indirect carbon emissions into the carbon emissions costs to assure an accurate scientific estimation. Indirect carbon costs incurred by heat and electricity consumption contribute significantly to several industries. Thirdly, we conducted a carbon price scenario analysis and addressed the carbon price criteria threshold in China.

3. Methodology

3.1. Research method

Inspired by the German Federal Environmental Agency research report, this study defines the short-term impact of Beijing's carbon emissions trading system on industry competitiveness as the carbon emissions cost in relation to the added value of a given industry. Therefore, we calculated the CO_2 emissions and multiplied the results by the instantaneous carbon market price to obtain the carbon emissions cost. This cost divided by the industry added value is the proportion of the carbon emissions cost to the industry added value, i.e., the carbon emissions cost per unit of added value, which can assess whether the industry competitiveness is affected by the carbon emissions trading system. Specifically, this study divides the carbon emissions cost into direct and indirect costs. The direct carbon emissions cost is the cost of CO_2 emissions generated by the main fossil energy consumption, and indirect costs refer to the cost of carbon emissions generated by heat and electricity consumption in a given industry. Thus, the carbon emissions cost per added value unit is defined as follows:

$$\frac{(DCO_2 + IDCO_2) \times BEA}{IAV} \tag{1}$$

where DCO_2 is the direct CO_2 emissions generated by an industry's fossil energy consumption, $IDCO_2$ reflects the indirect CO_2 emissions generated by an industry's heat and electricity consumption, BEA is the carbon emissions quota price in the Beijing carbon emissions market, and IAV is the industry added value. Therefore, $DCO_2 \times BEA$ and $IDCO_2 \times BEA$ are the direct and indirect carbon emissions costs of a given industry.

To calculate the direct and indirect carbon cost of the industry, it is necessary to estimate the carbon emissions of various industries. The widely accepted method for estimating CO_2 emissions was provided by the United Nations

Table 1. Nineteen selected industries in Beijing.

Number	Industry Sector
1	Agriculture, forestry, animal husbandry and fishery
2	Mining industry
3	Manufacturing industry
4	Production and supply of electricity, gas and water
5	Construction industry
6	Wholesale and retail trade
7	Transportation, warehousing and postal services
8	Accommodation and catering services
9	Information transmission, software, and information technology services
10	Finance
11	Real estate industry
12	Leasing and business services
13	Scientific research and technical services
14	Water conservancy, environment, and public facilities management
15	Residential services, repairs, and other services
16	Education
17	Health and social work
18	Culture, sports, and entertainment
19	Public administration, social security, and social organization

Intergovernmental Panel on Climate Change (IPCC) in the National Greenhouse Gas Inventories Guide (2006), and is defined as follows:

$$DCO_2 = \sum_i CO_{2,i} = \sum_i E_i \times NCV_i \times CEF_i \times COF_i \times (44/12) \tag{2}$$

where $CO_{2,i}$ and E_i are the carbon emissions and energy consumption of energy i, NCV_i is the average low calorific value, CEF_i is the carbon emissions coefficient, COF_i is the carbon oxidation factor, and 44 and 12 are the molecular weights of CO_2 and carbon, respectively.

3.2. Data source

According to the China National Economic Industry Classification Standards (2017), we selected 19 major industries (See Table 1) in Beijing to explore the impact of carbon emissions trading system on industry competitiveness. The GDP of these 19 industries and their respective energy consumptions were obtained from the Beijing Statistical Yearbook (2015–2017).

Among the major energy varieties, the coke and liquefied natural gas data were incomplete for several years, and the consumption in most industries was zero. To ensure comparability, these two energies were deleted, and nine energy varieties, coal, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas, and heat and electricity, were retained.

The carbon price data was derived from the day transaction price of the Beijing Environment Exchange from 2014 to 2016. After deleting the zero volume trading day in the Beijing carbon market, the average carbon price of 188 trading days in 2014 was approximately 54.89 Yuan/ton, the average price of 145 trading days in 2015 was 47.72 Yuan/ton, and the average price of 189 trading days in 2016 was 48.66 Yuan/ton.

For the estimation of the carbon emissions using formula (2), the IPCC method may overestimate the carbon emissions in China [17]. Therefore, this study improved the estimation method for calculating the direct CO_2 incurred by seven fossil energy sources of 19 industries in Beijing. IPCC Guidelines (2006) only present six fossil energy carbon emission factors. Therefore, to estimate the coal carbon emissions factor, we separately compounded bituminous coal and anthracite, with weighted averages of 80% and 20%, respectively. This estimation was possible because China's coal proportion has not significantly changed for a long time, and the proportion of bituminous coal has remained between 75% and 80%. The average low calorific value was provided by the China Energy Statistical Yearbook (2016), and the carbon oxidation factor was obtained from the Guidelines for the Establishment

Table 2. Fossil energy parameters.

Energy	Average low calorific value (kJ/kg, kJ/M^3)	Carbon emission factor (kgC/GJ)	Carbon oxidation factor
Coal	20908.00	26.36	0.93
Gasoline	43070.00	18.90	0.98
Kerosene	43070.00	19.60	0.98
Diesel	42652.00	20.20	0.98
Fuel oil	41816.00	21.10	0.98
Liquefied Petroleum gas	50179.00	17.20	0.98
Natural gas	38931.00	15.30	0.99

Table 3. Carbon emission factor for heat and electricity.

Category	Carbon emission factor
Heat	0.11 t CO_2/GJ
Electricity	7.88 t CO_2/104 kWh

Table 4. Direct and indirect carbon emissions of the 19 selected Beijing industries (2014–2016) (Unit: Ten thousand ton).

Industry	2014			2015			2016		
	DCO2	IDCO2	TCO2	DCO2	IDCO2	TCO2	DCO2	IDCO2	TCO2
1	92.96863	146.2528	239.2214	79.96498	145.78	225.745	63.4	154.61	218.01
2	8.997115	50.3007	59.29781	7.353635	39.7936	47.14723	6.08	34.26	40.34
3	724.3172	1778.25	2502.567	618.5968	1736.565	2355.162	537.23	1789.42	2326.65
4	3163.919	945.6435	4109.562	2961.681	924.3893	3886.07	2951.98	964.34	3916.32
5	117.8716	190.914	308.7856	117.4586	178.3915	295.8501	116.37	180.26	296.63
6	108.0011	398.6799	506.681	115.1917	409.4202	524.6119	132.82	423.34	556.16
7	2171.562	422.4439	2594.006	2221.123	438.1648	2659.288	2326.48	458.05	2784.53
8	235.8072	465.911	701.7182	247.6251	473.6862	721.3113	205.38	483.7	689.08
9	19.44283	383.1093	402.5521	21.19937	436.5729	457.7723	20.3	487.75	508.05
10	16.27398	170.8017	187.0757	12.57784	175.0174	187.5952	11.31	171.13	182.44
11	306.8533	632.6836	939.5369	288.8037	661.4065	950.2102	263.43	712.7	976.13
12	156.7148	381.7927	538.5075	144.1839	362.723	506.9069	155.78	373.56	529.34
13	113.6414	295.3706	409.012	108.5219	338.3378	446.8597	123.79	373.39	497.18
14	46.27051	108.2002	154.4707	39.56107	114.5673	154.1284	39.1	123.63	162.73
15	40.55459	42.7837	83.33829	33.76558	44.264	78.02958	32.11	47.86	79.97
16	140.6078	423.7642	564.372	142.2863	436.1853	578.4716	113.08	446.87	559.95
17	47.46497	168.1051	215.5701	45.02696	171.6444	216.6714	38.79	183.23	222.02
18	21.91682	153.021	174.9378	22.68147	174.0124	196.6939	20.98	186.7	207.68
19	68.64269	244.6107	313.2534	64.07488	241.6633	305.7382	50.63	244.97	295.6

of Provincial Greenhouse Gas Inventories (2011) issued by the China NDRC. The seven fossil energy parameters are listed in Table 2.

To estimate the indirect CO_2 emissions generated by the consumption of heat and electricity for the 19 selected industries, this study used the method in the Guidelines for Shanghai Greenhouse Gas Emissions Accounting and Reporting (2012) issued by the Shanghai Municipal Development and Reform Commission, which is defined as follows:

$$IDCO_2 = Activity\,level \times Carbon\,emission\,factor \tag{3}$$

where the activity level is the consumption of heat and electricity in the various industries. The indirect carbon emission factor of heat and electricity are shown in Table 3.

According to formulae (2) and (3), the estimations of the direct and indirect CO_2 emissions caused by the consumption of the seven energy categories and the heat and electricity consumption of the 19 selected industries in Beijing from 2014 to 2016 are provided in Table 4.

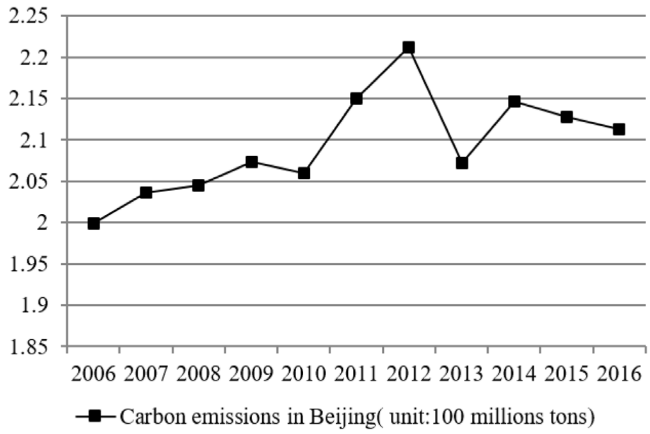

Fig. 1. Trend in Beijing carbon emissions from 2006 to 2016.

4. Impact of Beijing carbon market on industry competitiveness

Fig. 1 reflects the total carbon emission changes in the 19 selected Beijing industries from 2006 to 2016. The carbon emission variations in Beijing in the past decades can be approximately divided into two stages: before the start of the carbon trading system in 2013, and after the establishment of carbon emissions trading system.

Fig. 1 shows that the Beijing total carbon emissions increased continuously from 199.9 million tons in 2006 to 221.2 million tons in 2012. Moreover, the total carbon emissions increased sharply from 2010 to 2012, with an annual increase of 7.4%, and reached a maximum peak significantly higher than in past decades.

The implementation of the clear policy signal for carbon emissions trading system experienced a rapid decline in the carbon emissions in Beijing to 207.2 million tons. However, an increasing trend is again observed for the 2013–2014 period, which may be attributed to the reaction of enterprises to the establishment of initial moderate CETS or the policy lag effects of the establishment of this trading system at the end of 2013. However, carbon emissions have steadily declined overall 2014 as the role of CETS has become increasingly significant.

4.1. Estimation of the carbon market impact on industry competitiveness

In this section, the direct and indirect cost incurred by the Beijing carbon trading system for the 19 selected industries was calculated, and the impact on industry competitiveness was estimated accordingly.

A calculation of the direct and indirect carbon emissions of the 19 industries (Table 3) multiplied by the current carbon price was used to obtain the direct and indirect costs resulting from the CETS. Afterward, using the industry competitiveness estimation formula (1), the additional costs proportion caused by carbon emissions trading system to the industry added value was calculated. The results are presented in Figs. 2, 3, and 4. The light-colored area in these figures indicates the additional costs proportion caused by heat and electricity consumption to the industry added value. The black area represents the additional costs proportion caused by fossil energy consumption to the industry added value.

Overall, the results presented in Figs. 2–4 indicate that during the 2014–2016 period, the carbon emissions costs proportion to the added value in industry 4 (production and supply of electricity, gas, and water), industry 7 (transportation, warehousing, and postal services), and industry 8 (accommodation and catering services) are significantly higher than the remaining 16 industries, indicating that three industries are more affected by CETS. The proportion of the carbon emissions cost to the added value in 2014, 2015, and 2016 was 3.02%, 2.47%, and 2.35% for industry 4; 1.50%, 1.29%, and 1.28% for industry 7; and 1.06%, 0.87%, and 0.84% for industry 8. These results indicate a declining trend in the impact of CETS on these three industries. Moreover, the high proportion of the carbon emissions cost to the added value for industries 4 and 7 were attributed to the high carbon emissions costs incurred by fossil energy consumption in these two industries. Therefore, an improvement in the energy consumption structure of these two industries would decrease the impact on the industry competitiveness. The excessive heat and electricity consumption of industry 8 increased the indirect carbon emissions cost. Although these three industries

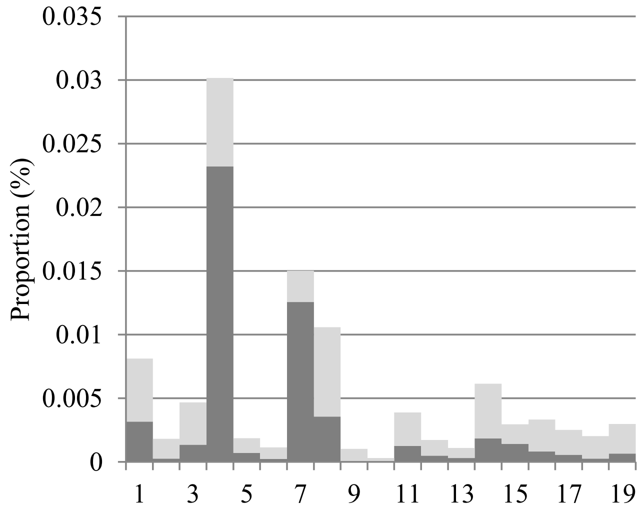

Fig. 2. Proportion of carbon emissions cost to industry added value in 2014.

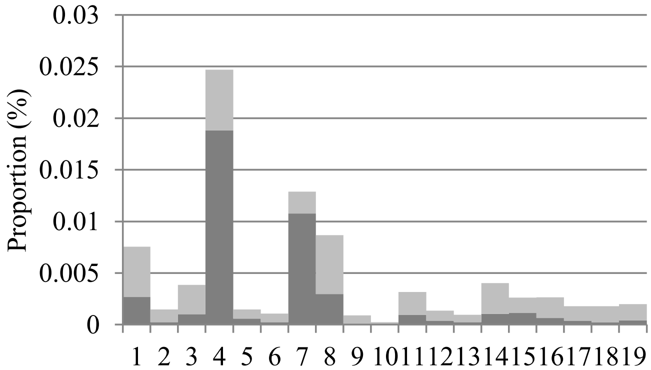

Fig. 3. Proportion of carbon emissions cost to industry added value in 2015.

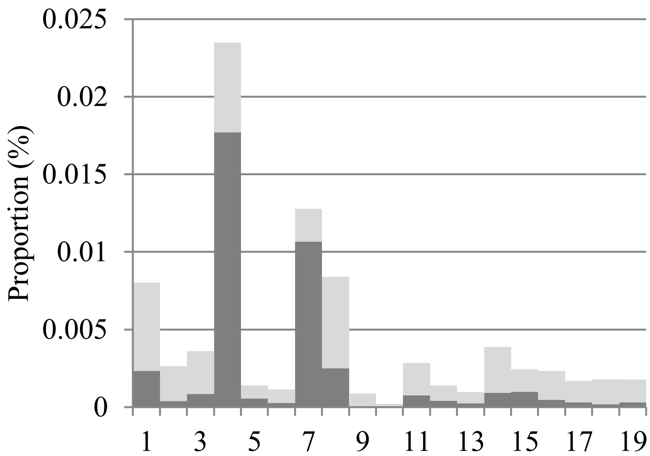

Fig. 4. Proportion of carbon emissions cost to industry added value in 2016.

are the most affected by CETS, their total added value accounts for only 10% of the Beijing regional GDP, and thus, the system has little impact on Beijing's economic development. Moreover, industry 3, 6, 9, 10, and 13 are the five biggest contributors to Beijing's GDP, and their total added value account for 58% of the regional GDP. However, Figs. 2–4 indicate that CETS only significantly impacts industry 3 (the manufacturing industry).

In the German Federal Environmental Agency Report 2008 [16], EUETS adopted a 5% standard on their industry competitiveness impact. When carbon cost accounts for more than 5% of the industry added value, CETS is considered to significantly impact industry competitiveness. Based on this 5% standard, the impact of the carbon trading system on the competitiveness of the 19 selected industries could be neglected in the past three years. The average carbon cost proportions of the 19 industries in 2014, 2015, and 2016 were 0.53%, 0.44%, and 0.43%, respectively. Even considering the incomplete carbon emissions calculation, the carbon trading system has little impact on Beijing's industry competitiveness. This indicates that the carbon trading system significantly reduced the total carbon emissions in Beijing and simultaneously decreased industry competitiveness. Although the carbon trading system's impact on industry 4 (production and supply of electricity, gas, and water) in the past three years increased to 3.02%, it remained below the 5% standard.

At the beginning of Beijing's carbon trading system, regulated industries comprised predominantly energy-intensive industries such as the cement and petrochemicals industries, which are concentrated in industry 2, 3, and 4. The proportion of carbon costs to the industry added value in industry 2 (mining) was 0.18%, 0.15%, and 0.26% in 2014, 2015, and 2016. This proportion in industry 3 (manufacturing) was 0.47%, 0.38%, and 0.36% in 2014, 2015, and 2016. Evidently, CETS does not significantly impact the industry competitiveness of regulated industries. Moreover, the impact on industry 2 and 3 is mainly reflected in the indirect cost caused heat and electricity consumption.

4.2. Scenario analysis of the impact of different carbon prices on industry competitiveness

Because the average price of Beijing's carbon trading market has been stable at approximately 50 Yuan/ton for the past four years, the following section explore the impact of a 60 Yuan/ton price and 10 Yuan interval on industry competitiveness. For convenience, we selected data on carbon emissions and the industry added value from various industries in Beijing in 2016 to estimate the impact of the carbon trading system on industry competitiveness under price fluctuations. Based on EU ETS industry competitiveness impact standard of 5%, Fig. 5 demonstrates that for a carbon price equal to or less than 100 Yuan/ton, the impact of Beijing's carbon trading system on industry competitiveness is negligible. Moreover, no industry reaches the impact standard of 5% under these conditions. Only when the price increased to 100—110 Yuan/ton did industry 4 reach the 5% standard, at which point the industry becomes seriously affected (Fig. 6). The added values of these affected industries accounted for 15.27% of Beijing's total GDP. When the carbon price exceeded 180 Yuan/ton and reached a cost of 200 Yuan/ton, industry 4 and 7 were significantly impacted (Fig. 6), and the added values of these two industries accounts for 26.1% of the GDP. Furthermore, when the carbon price reached a high of 300 Yuan/ton, four industries were significantly impacted, and the proportion of their added values to the GDP was 29.6%. Therefore, a gradual increase in the carbon price increases the number of affected industries and the impact of the carbon emission trading system on industry competitiveness and economic development. For example, in 2016, each 10 Yuan/ton increase in the carbon price advanced the impact of the carbon trading system on the competitiveness of the 19 selected industries by 1.68%.

4.3. Analysis of industry competitiveness impact using the global carbon price

In 2017, the World Bank estimated [18] that, according to global binding carbon emission reduction targets, to accomplish the temperature target of the Paris Agreement, the global carbon price should range between 40 and 80 US dollars/ton by 2020, equivalent to 250–500 Yuan/ton. When the upper limit price is exploited to estimate the impact of Beijing's carbon trading system on industry competitiveness, four industries are affected within the 300–500 Yuan/ton price range. However, the impacts on industry 4 and industry 7 reached a high of 24.14% and 13.12%, respectively, at a carbon price of 500 Yuan/ton, significantly exceeding the 5% warning line. Moreover, industry competitiveness is significantly weakened, and economic development could not pay such a high carbon price. Therefore, overpaid carbon prices, especially in accordance with global uniform standards, will have a negative impact on economic development in China. Regarding the social cost of carbon (SCC), recent reports have suggested that a lower carbon price is not necessarily the most efficient price, and the efficient carbon price

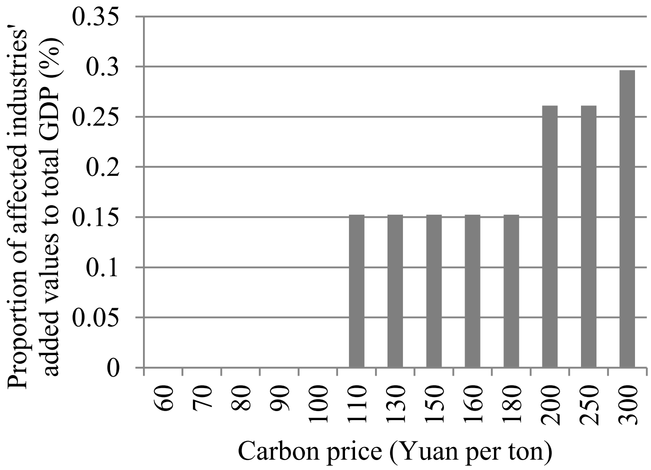

Fig. 5. Sensitivity analysis under impact standard of 5%.

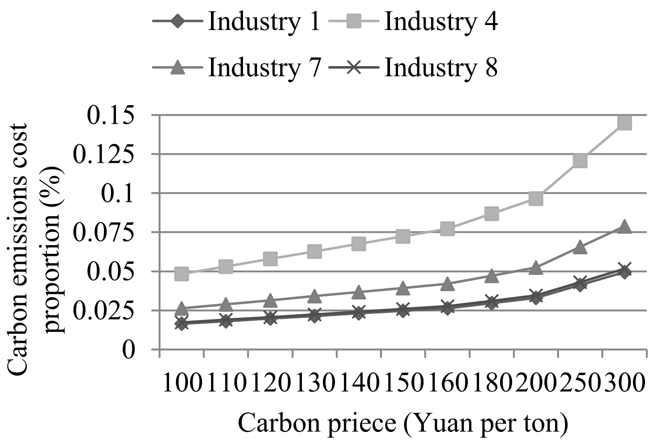

Fig. 6. Industry competitiveness impact for various carbon prices.

has been determined to be approximately 40 US dollars/ton in China [19]. Even when calculated with this price, the two affected industries exceed the 5% impact standard, and their added values account for 26.1% of Beijing's GDP. Therefore, such price is also too high for the early development of China's carbon markets.

4.4. Criteria threshold of the carbon price and the impact of industry competitiveness on the Beijing carbon market

According to the previous scenario analysis, an initial increase in the carbon price affects industry 4 first. To ensure that the impact of Beijing's carbon market on the competitiveness of the 19 selected industries is less than 5%, industry 4 can be used to measure the carbon market price threshold in Beijing. Based on the total carbon emissions and added value of industry 4 in 2016, an industry competitiveness evaluation model indicates a carbon market price less than 103.58 Yuan/ton producing a negligible impact on the 19 industries. Therefore, the theoretical threshold of the carbon price in the Beijing carbon market is 103.58 Yuan/ton when other conditions remain unchanged.

Contrastingly, a lower carbon price should be maintained to protect industry competitiveness and reduce the impact on economic development in the early stages of the carbon market. However, considering the industry profitability between China and developed countries, China could adopt a standard below 5% in EU. Considering that more than 75% of global carbon markets are below 10 US$/ton [20], this study used 60 Yuan/ton as the reference price to conduct the subsequent analysis in Beijing carbon market. Moreover, we determined that the proportion of carbon emission costs of industry 4 to the added value reaches 2.89%, the highest level recorded for the 19 selected industries. Therefore, 2.89% could be set as the threshold of the industry competitiveness impact in Beijing. This threshold value is concurrent with most carbon markets in the world and reduces the impact of industry competitiveness. As long as carbon prices continue to rise, the industry range affected by carbon trading will continue to expand.

5. Conclusions and policy implications

This study calculated the direct and indirect carbon emissions of 19 selected industries in Beijing from 2014 to 2016 and established the industry competitiveness model to estimate the additional direct and indirect carbon emission costs of the 19 industries after the establishment of the Beijing in 2013. Furthermore, the competitiveness variations in these industries are analyzed, and the impacts on industry competitiveness under different carbon price scenarios were determined.

Our results indicated that the Beijing does not significantly impact economic development. Among the 19 industries, only three industries were influenced by the fluctuations in the carbon price, while the proportion of the total added values of these three industries to the Beijing GDP is only approximately 10%. Among the top five contributing industries to the GDP, CETS did not impact four of the industries, and the fifth (manufacturing) recorded an impact of 0.4%.

Carbon emission costs vary significantly for the various industries in Beijing. The electricity, gas, water production and supply, transportation, warehousing and postal industries consume more fossil energy, thereby resulting in a higher direct carbon emissions cost. Moreover, more heat and electricity were consumed in the accommodation and catering industries with a higher indirect carbon emissions cost. Indirect carbon emissions costs are relatively high for the mining and manufacturing industry.

The impact of the Beijing carbon emissions trading system on industry competitiveness is significantly lower than that of developed countries. Under the current carbon price level, the Beijing carbon emissions trading system reduces the total carbon emissions and lowers the annual impact on industry competitiveness. Although compared with developed countries, there is scope for further increase in the Beijing carbon market price, and the highest price can reach 100 Yuan/ton; exceedingly high price will negatively affect industry competitiveness.

Therefore, in addition to improving and perfecting the carbon emissions trading system, we propose three approaches to slow down the impact of the CETS on industry competitiveness and reduce the carbon emissions cost.

Firstly, CETS should be combined with other energy policies to reduce industry carbon emissions cost-efficiently. It is impossible to rely solely on the CETS to achieve reduction targets, and the CETS and other polices could be incorporated into an interaction effect [21]. The impact of CETS on the direct and indirect carbon emission costs for the different industries varies significantly. Carbon markets policies should be integrated with strict energy and electricity regulations and industrial structure optimization.

Secondly, the carbon price should be compatible with the bearing capacity of the various industries. It is established that CETS impacts regulated industries. Policymakers should undertake more regulatory measures to maintain market prices within a reasonable range and correct the severe imbalance between supply and demand [22]. A key point is to reduce the impact within a controllable range. All these basic national conditions indicate that the carbon market price setting in China should be tailored to local conditions and differentiated according to industry and region. More cautious and reasonable carbon prices are beneficial for the various industries and regions in China.

Third, China should adhere to the common but differentiated responsibilities principle to set carbon prices and other rules in the world. In addition to considering the basic national conditions of economic development and industry characteristics, China needs to adjust global carbon market principles according the various countries in the global carbon market system.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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