



Analysis of influencing factors of the carbon dioxide emissions in China's commercial department based on the STIRPAT model and ridge regression

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Abstract

Commercial department assumes the vital part in energy conservation and carbon dioxide emission mitigation of China. This paper applies the time-series data covering 2001–2015 and introduces the STIRPAT method to research the factors of commercial department's carbon dioxide emissions in China. The combination of STIRPAT method and ridge regression is first adopted to research carbon dioxide emissions of commercial department in China. Potential influencing factors of carbon dioxide emission, including economic growth, level of urbanization, aggregate population, energy intensity, energy structure and foreign direct investment, are selected to establish the extended stochastic impacts by regression on population, affluence and technology (STIRPAT) model, where ridge regression is adopted to eliminate multicollinearity. The estimation consequences show that all forces were positively related to carbon dioxide emissions in China's commercial department except for energy structure. Energy structure is the only negative factor and aggregate population is the maximal influencing factor of carbon dioxide emissions. The economic growth, urbanization level, energy intensity and foreign direct investment all positively contribute to carbon dioxide emissions of commercial department. The findings have significant implications for policy-makers to enact emission reduction policies in commercial sector. Therefore, the paper ought to take into full consideration these different impacts of above influencing factors to abate carbon dioxide emissions of commercial sector.

Keywords China's commercial department · Carbon dioxide emission · STIRPAT method · Ridge regression

Introduction

It is known that factitious carbon dioxide emissions have become a prime culprit for environmental degradation inducing a negative impact on human survival. China has turned into the largest source of carbon dioxide emissions in the world in 2007. In the meantime, China generated about 10.4 billion tons carbon dioxide emissions in 2015, reaching 29% of the aggregate emissions of the world. Therefore, China ought to exert more efforts in energy conservation and emission mitigation. China has declared that its carbon dioxide emissions will crest and accomplish 11.7 billion tons around 2030. The

target has resulted in important impetus to carbon dioxide emission mitigation in many fields. On account of the great potential in emissions, the commercial department is a vital department for abating carbon dioxide emissions in China. Hence, it is meaningful for the commercial department to promote emission reduction, which can facilitate environmental policy implementation. As a result, comprehending and exploring the prime influencing factors of commercial department's carbon dioxide emissions will exert a positive impact on emission abatement in China.

Commercial department is a vital impetus for China's development in the future, which means an environment-friendly and sustainable development concept. In this paper, the commercial department is disparate from the conventional commercial model, which was defined by the US Energy Information Administration. The commercial model in America incorporates stores, schools, gymnasiums, hospitals, libraries, museums, warehouses and so on. According to Lin and Wang (2015), the study integrates wholesale and retail trade, hotel and catering services and other service industries

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as the commercial department in China. Commercial department has obtained distinguished achievements in recent decades. In 2015, commercial department ushered a 332.84 Mtce (million ton coal equivalent) energy consumed in China, reaching 7.7% in holistic energy consumed. Meanwhile, carbon dioxide emissions of commercial sector in China achieve 818.80 Mt in 2015, reaching 6.8% of holistic carbon dioxide emissions. In China, the shift in energy consumed from coal to electricity in commercial department is undergoing. Moreover, electric power has been the most significant terminal energy in commercial field. In the meantime, with the development of the internet and new retail, the transformation in commercial department will continue. The carbon dioxide emissions had augmented from 213.2 to 805.5 million tons in China's commercial department during 2000–2015 with an annual growth rate of 9.3%. Rapid development in commercial department indicates that there are massive energy consumption potentials in the future.

The remanent sections of this study will be organized as follows: the “[Literature review](#)” section briefly reviews the current literature. The “[Methodology](#)” section depicts method applied and demonstrates economic models. The “[Data source and description](#)” section affords data sources and description. The “[Empirical results](#)” section researches the consequences of empirical analysis, followed by the conclusions and policy implications in the “[Conclusions and policy implications](#)” section.

Literature review

There are many researches that have widely researched the driving forces of carbon dioxide emissions in alien countries and China. These methods applied in the literature can be approximately separated into four categories.

First: bottom-up method. On the basis of a bottom-up approach, Lee et al. (2017) examined how to downscale carbon dioxide emissions in Taiwan and propound feasible policy implications. Moreover, Brunke and Blesl (2014) employed the bottom-up model to research the carbon dioxide emissions in German steel industry.

Second: index decomposition method. On the basis of an LMDI (Logarithmic Mean Divisia Index) decomposition approach, Babak et al. (2017) conducted three variates of decomposition analyses of influencing factors of Iran's carbon dioxide emissions from energy consumption during 2003–2014. According to energy intensity and industrial structure, Choi and Oh (2014) examined the shift in Korea's manufacturing industry emissions. On the basis of LMDI, Ouyang and Lin (2015) investigated influencing indicators of industrial department's carbon dioxide emissions in China.

Third: system optimization method. Kang and Liu (2015) adopted a multiobjective optimization method to examine a

heat exchanger network's carbon dioxide emissions. Similarly, Yang et al. (2017) adopted a multiobjective optimization method basing on nondominated sorting genetic algorithm-II to investigate the allocation of energy conservation and sustainable energy facilities in campus. Chen et al. (2013) explored how to facilitate carbon dioxide emission governance on regional electric power systems with an inexact robust optimization method.

Fourth: econometric method. Miao et al. (2016) employed the zero sum gains data envelopment model to examine the efficient allocation of China's carbon dioxide emissions. Xu and Lin (2015a) adopted a panel co-integration approach to research the carbon dioxide emissions and renewable energy.

Amounts of researches also concentrate on carbon dioxide emission in China. Lu et al. (2018) applied the interval-fuzzy possibilistic programming method to investigate how to optimize energy governance system with carbon dioxide emission constraint in China. Feng et al. (2017) adopted DEA (index decomposition analysis) models to investigate how to achieving the potential of emission mitigation in China. According to the input-output structural decomposition method, Wei et al. (2017) investigated influencing indicators of energy-related carbon dioxide emissions in Beijing.

Due to China's commercial department embraces huge carbon dioxide emission potentials, so there will be of significance in researching main influencing factors of carbon dioxide emissions of commercial department. Wang and Lin (2017) adopted the STIRPAT and VAR methods to estimate carbon dioxide emissions of commercial department in China during 1980–2014 and proposed some feasible reduction strategies. Wang and Lin (2018) adopted nonradial directional distance function to estimate carbon dioxide efficiency of commercial department in China.

Although the influencing factors of carbon dioxide emission of commercial department had been investigated, it is insufficient for the current researches about carbon dioxide emissions of commercial department in China. Meanwhile, most of these researches apply the conventional linear methods which often produce multicollinearity to study the carbon dioxide emissions. Based on the above analysis, this paper adopts the STIRPAT and ridge regression to research the primary driving forces of carbon dioxide emission of commercial department in China and proposes some policy recommendations.

The paper is distinctive from other investigations for the following reasons. First, most of investigations apply the conventional linear methods to study the carbon dioxide emissions and approximately ignore the multicollinearity between variables. The ridge regression in this paper can effectively eliminate multicollinearity to avoid pseudo-regression. Second, the study uses foreign direct investment as an influencing factor to study carbon dioxide emissions in China's commercial department. This paper indicates that

foreign direct investment is also a major driver of carbon dioxide emissions in China's commercial department. Finally, in China's commercial department, the type of final energy gradually altered from coal to electric power with the development of economy. So, energy structure in this paper is presented as standard coal consumption consumed by electricity generation dividing its aggregate energy consumption.

Methodology

STIRPAT model construction

Many scholars apply the *IPAT* (I = human impact, P = population, A = affluence, T = technology) identity ($I = PAT$) to investigate environmental contamination (Hofmann et al. 2016):

$$I = P \cdot A \cdot T \quad (1)$$

I depicts pollution level here, P represents the number of people, A and T denote the economic and technological conditions in one country, respectively. However, the *IPAT* model embodies its shortcomings. For the purpose of comprehensively analysing the forces governing environmental change, based on the *IPAT* model, we introduced the *STIRPAT* model (Dietz and Rosa 1997), and it is presented as below:

$$I_t = aP_t^b A_t^c \xi_t \quad (2)$$

a denotes a constant term; in Eq. (1), variates P , A and T have been interpreted; parameters b , c and d respectively denote elasticities of environmental implications in reference to P , A and T . ξ_t means a stochastic disturbance term. The subscript t represents the year. *STIRPAT* models have been applied for exploring the influencing forces of environmental contamination (Shahbaz et al. 2016). In order to eliminating potential heteroscedasticity, we take all the variates logarithmically. Hence, Eq. (2) could be rewritten as:

$$\ln I_t = \ln a + b(\ln P_t) + c(\ln A_t) + d(\ln T_t) + \xi_t \quad (3)$$

The P denotes aggregate population (10^4 persons) here. The per capita GDP (yuan) can be presented by A and T demonstrates energy intensity (EI). Hence, Eq. (3) will be rewritten as below:

$$\ln LCO_{2t} = \ln a + b(\ln LPOP_t) + c(\ln LGDP_t) + d(\ln LEI_t) + \xi_t \quad (4)$$

where CO_2 denotes carbon dioxide emissions of commercial department (10^4 t), POP depicts aggregate population (10^4 people) and GDP represents economic development level. EI signifies energy intensity and can be demonstrated by energy consumed of commercial department divided by its aggregate output (percent). Based on above analysis, the dynamic

polluting emissions have been investigated by Lin and Zhao (2016). a and ξ have been presented in Eq. (4).

In order to conduct an in-depth exploration, we introduce urbanization, energy structure and foreign direct investment into *STIRPAT* model owing to the particular situations of commercial department. To begin with, China is embracing rapid urbanization (Xu and Lin 2015b). Expanding urban residents demand substantial commercial goods and infrastructure, which will give birth to an augment in carbon dioxide emissions of commercial department. Therefore, it is indispensable to incorporate urbanization level into the model. Secondly, energy structure (demonstrated as standard coal consumption consumed by electricity generation dividing its aggregate energy consumption) is a significant driving forces. In China's commercial department, the type of final energy gradually altered from coal to electric power with the development of economy. In China's commercial department, coal consumption accounts for about 19.7% of aggregate energy consumed with only 57.53 Mtce in 2014, which is conducive to carbon dioxide emission abatement. Consequently, we incorporate energy structure into the model. Finally, numerous papers have indicated that foreign direct investment (FDI) is also vital factor of carbon dioxide emissions (Xu and Lin 2016). Hence, this paper also incorporates foreign direct investment into the *STIRPAT* model.

According to the analysis above, we specify a mathematical model of carbon dioxide emissions of commercial department as:

$$\begin{aligned} LCO_{2t} = & \ln a + \beta_1 \ln LGDP_t + \beta_2 \ln LURB_t + \beta_3 \ln LPOP_t \\ & + \beta_4 \ln LEI_t + \beta_5 \ln LES_t + \beta_6 \ln LFDI_t + \xi_t \end{aligned} \quad (5)$$

where CO_2 (carbon dioxide), Eq. (4) has presented the variates GDP , POP and EI . URB represents the urbanization and can be calculated by urban population divided by aggregate population. ES denotes energy structure (standard coal consumption consumed by electricity generation dividing its aggregate energy consumption). FDI signify the foreign direct investment.

Ridge regression

Owing to interaction terms of the input variables in Eq. (5), the model is likely to undergo obvious multicollinearity. This violates the indispensable condition to OLS (ordinary least squares) to be unbiased. If model terms are correlative and the columns of the design matrix X show the approximate linear dependence, matrix $(X^T X)^{-1}$ will be close to singular. As a result, the least-squares estimate (Kutner and Michael 2005) becomes significantly sensitive to random

errors in the observed response Y , which will generate a large variance.

$$\hat{\beta} = (X^T X)^{-1} X^T Y \tag{6}$$

A solution to the problem of multicollinearity is to abandon the usual least-squares procedure and resort to biased estimation techniques. The ridge regression is one of the biased estimation adopted for above goal, which was proposed by Hoerl and Kennard (1970). Ridge regression estimation is given by

$$\hat{\beta} = (X^T X + kI)^{-1} X^T y, k > 0 \tag{7}$$

k means a biasing parameter or ridge parameter that meets $k > 0$, and X is the explanatory variate matrix. I is unit matrix, and Y is the explained variate vector. Generally, the ridge regression estimates are computed for various increasing values of k , from $k = 0$, until an optimum value of k is determined for which all the regression coefficients appear to have stabilized. The paper adopts the ridge trace plot approach. By plotting values of the coefficients against the consecutive values of k , the curve referred to as the ridge trace is obtained. Coefficients are estimated with various levels of k from zero to one. The $\hat{\beta}_i$ coefficients are then plotted with respect to values of k and the optimal value of k is obtained at the point where the $\hat{\beta}_i$ coefficients seem to stabilize.

Data source and description

Data source

All data were collected from the China Statistical Yearbooks (2001–2015). According to multiple kinds of fossil energy consumed and their carbon dioxide emission factors, this paper figures the commercial department’s carbon dioxide emissions during 2001–2015. Definitions of the relevant variates were presented in Table 1. At the same time, Table 2 demonstrates the description of variates involved in this paper.

Table 1 Definition of the variates involved in this research

Variate	Definition	Units of measurement
CO ₂	Aggregate CO ₂ emission of commercial department	10 ⁴ t
GDP	Per capita GDP	Yuan
URB	The level of urbanization	Percent
POP	Aggregate population	10 ⁴ people
EI	Energy intensity	Tce per 10,000 yuan
ES	Energy structure in the commercial department	Percent
FDI	Foreign direct investment	10 ⁴ dollar

Data description

According to annual data of explanatory and explained variates, this paper explores the relevant changes of commercial department’s carbon dioxide emissions, per capita GDP, level of urbanization, aggregate population, energy intensity, energy structure and foreign direct investment during 2001–2015. As presented in Fig. 1, carbon dioxide emissions in commercial department manifested the fast-growing tendency embracing the annual growth rate of 9%. Similarly, per capita GDP augments from 8717 (yuan) in 2001 to 50,251 (yuan) in 2015, which represents the annual growth rate of about 12%. The level of urbanization achieved the annual growth rate of 3% during 2001–2015. Aggregate population slowly increases from 127,627 × 10⁴ persons in 2001 to 137,462 × 10⁴ persons in 2015, with the annual growth rate of 0.5%. Energy consumption per 10⁴ yuan demonstrated the descending tendency, signifying that the energy efficiency in commercial department gradually enhanced. The share of electric power consumed to aggregate energy consumed increased from 49.84% in 2001 to 73.32% in 2015, which indicates that energy structure has been gradually optimized. Foreign direct investment also appeared a trend of rapid growth with the annual growth rate of 17.1%.

Empirical results

The section presents the primary findings of the study. The “[Multicollinearity test](#)” section provides the results of the multicollinearity test and OLS (ordinary least square) regression. The “[Ridge regression estimation](#)” section implements the ridge regression. Analysis of the results will be settled in the “[Analysis of results of ridge regression](#)” section.

Multicollinearity test

Actually, economic growth, urbanization, aggregate population, energy intensity, energy structure and foreign direct investment are mutual promotion and close connection with commercial development. As is shown in Tables 3 and 4, the correlations of all the variables are

Table 2 Statistical description of all variates involved in this model

Variate	Units of measurement	Mean	Std. dev.	Min	Max
CO ₂	10 ⁴ tons	4737.602	1929.851	2239.043	8187.98
GDP	Yuan	26,128.13	14,460.96	8717	50,251
URB	Percent	47.06554	5.926168	37.65974	56.09987
POP	10,000 persons	132,695.1	3088.362	127,627	137,462
EI	Tce per 10 ⁴ yuan	0.227803	0.059733	0.156305	0.319357
ES	Percent	65.19747	9.010651	49.84418	76.77721
FDI	10 ⁴ dollar	574,348.7	427,894.9	93,264.00	1,245,711

high and the VIF values, which is the most common criteria (Read and Belsle 1994) of economic growth, urbanization, aggregate population, energy intensity, energy structure and foreign direct investment, are higher than 10. Severe multicollinearity exists between these variates. Owing to the reason of possible interaction between variates, the variates' marginal impact cannot be reflected by regression coefficients obtained through OLS.

Ridge regression estimation

The validity of the ridge regression proposed could be verified with credible indexes (adjusted R^2 , F test and t test). Table 4 indicates that regression equation is significant (F statistic sig. < 0.05) and the fitting degree (adj. $R^2 = 0.999$) is excellent. However, two explanatory variates (URB and FDI) are not significant (t statistic sig. > 0.05).

Ridge regression was adopted for estimating coefficients in STIRPAT. Eq. (7), Fig. 2 and Fig. 3 respectively illustrate ridge trace and the relationship between R^2 and k . The coefficients of all explanatory variates change quickly at first with the increase of k value and then turn to be stable after $k = 0.3$. Figure 3 demonstrates that R^2 of ridge regression has a high change rate before $k = 0.3$, and the rate becomes much lower from the k value of 0.3. Consequently, the smallest value of k ($k = 0.3$) could be operated with the high adjusted R^2 of 0.950. Hence, it could be reasonable to choose $k = 0.3$ in this paper considering great interpretability.

F sig. is 0.00000873 (< 0.05), which signifies that there is a linear link between explanatory variates and explained variate. Meanwhile, the constant term and coefficient's t sig. of all explanatory variates can satisfy requirement (< 0.1). Thus, all explanatory variates ought to be introduced into the regression equation. Details of the data involved are presented in Table 5.

Eventually, the fitted ridge regression equation is as follows:

$$\ln E = -44.81 + 0.13 \ln GDP + 0.69 \ln URB + 4.01 \ln POP + 0.17 \ln EI - 0.22 \ln ES + 0.06 \ln FDI \quad (8)$$

Analysis of results of ridge regression

Table 5 presents the estimate consequences of linear effects of influencing factors of commercial department's carbon dioxide emissions in ridge regression. All estimated coefficients were statistically significant with level of 1%, 5% or 10% (Eq. (8)).

Elasticity of aggregate population is greatest (4.01), signifying that the 1% augment in aggregate population can result in the 4.01% augment in carbon dioxide emissions while other forces are constant. It means that aggregate population is positively related to commercial department's carbon dioxide emissions. Estimate results indicate that aggregate population is primarily responsible for commercial sector's carbon dioxide emissions.

Elasticity of the level of urbanization is 0.69, indicating that the 1% augment urbanization can result in the 0.69% augment in carbon dioxide emissions while other factors are unaltered. It means that the surge in the level of urbanization produces a rapid augment in carbon dioxide emissions. The estimated results are supported by Wang and Lin (2017), which indicates that urbanization is a primary source of commercial department's carbon dioxide emissions in China.

Energy intensity in commercial department possesses the elasticity of 0.17. This means that energy intensity is also a primary factor of carbon dioxide in commercial department. The estimated consequence is consistent with Xu and Lin (2015c), which indicates that energy intensity is also a main source of carbon dioxide emissions in China.

Elasticities of energy structure are -0.22 , manifesting that the 1% augment of electric power will result in -0.22% decline in carbon dioxide emissions while else factors maintain unchanged. This signifies that electricity consumption will be the primary contributor of carbon dioxide emission of commercial department; the consequence could be demonstrated by Tian et al. (2016), they indicated that a good deal of coal consumption results in the commercial department emitting large-scale massive CO₂. The elasticities of economic development level and foreign direct investment are 0.13 and 0.06 respectively and are all positive.

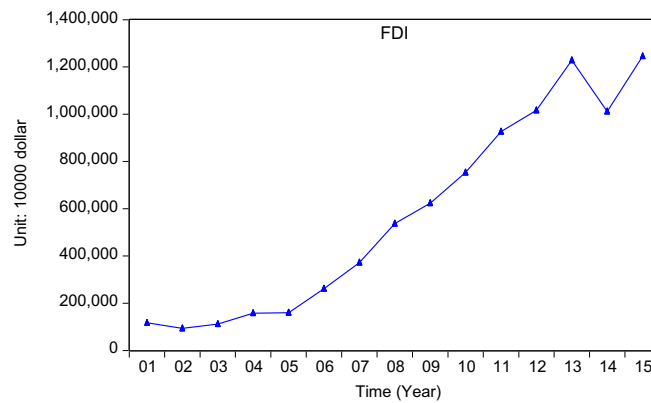
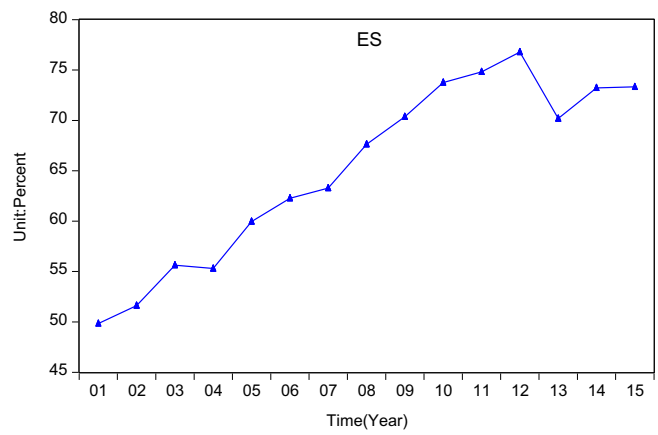
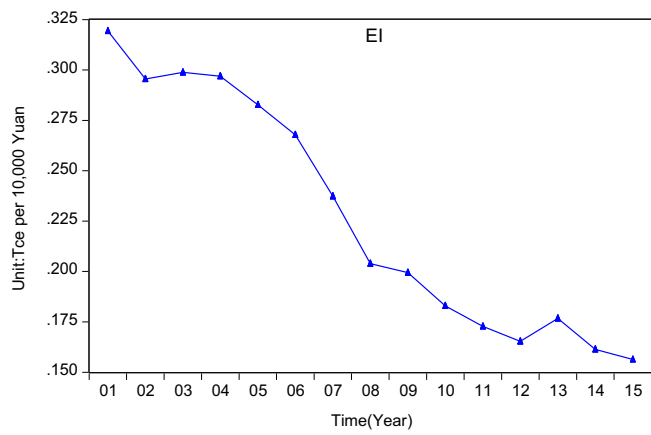
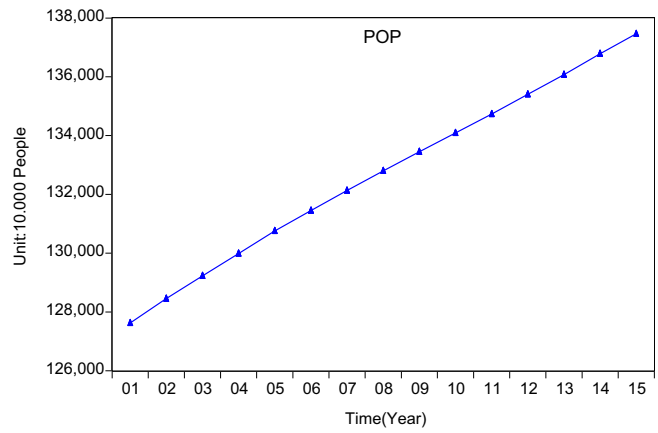
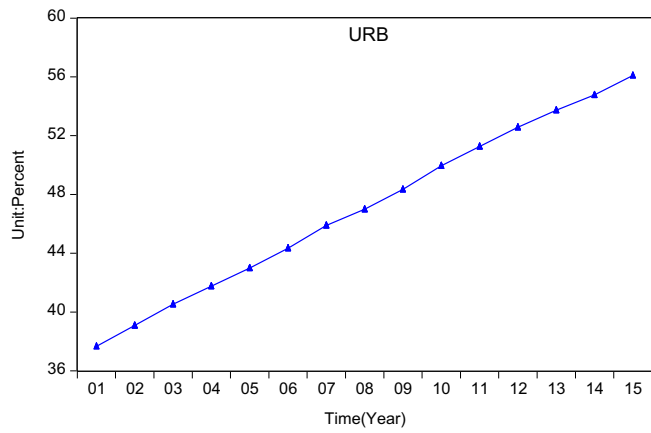
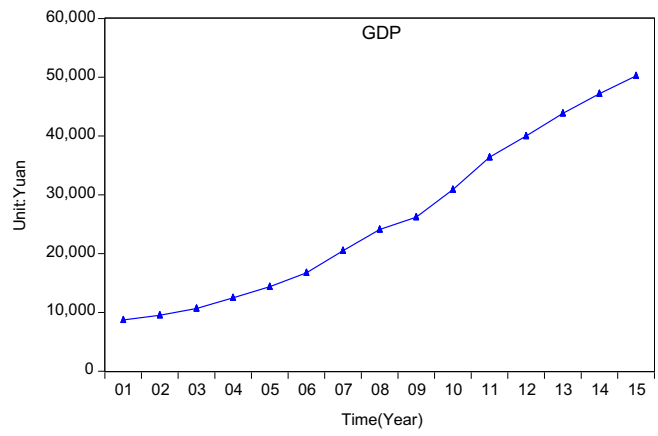
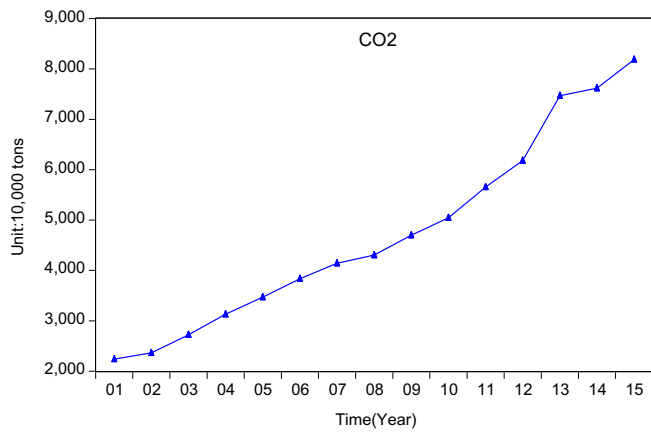


Fig. 1 The tendencies of the carbon dioxide emissions, per capita GDP, urbanization level, aggregate population, energy intensity, energy structure and foreign direct investment during 2001–2015

Conclusions and policy implications

Basing on time-series data of commercial department in China covering 2001–2015, the study researches the influencing factors of carbon dioxide emissions of commercial department with the STIRPAT and ridge regression. The consequences indicate that the total population shows a positive linear effect and total population is a maximal influencing factor. It is the result that carbon dioxide emissions of commercial department mainly rely on commercial activities of a growing number of consumers, which is closely related to aggregate population. Level of urbanization also shows a positive pattern to carbon dioxide emissions. Since the enhancing of the urbanization level means that more urban residents with high income will become potential consumers, which also is the primary source of carbon dioxide emissions. Impact of energy intensity exhibits a positive elasticity of 0.17. A significantly positive coefficient demonstrates that low energy efficiency will be injurious for abating carbon dioxide emissions in commercial department. Energy structure is negatively related to carbon dioxide emissions due to more using of electricity not coal will reduce carbon dioxide emissions. The economic development level and foreign direct investment also augment the carbon dioxide emissions of commercial department, since there will be more capital and technology to invest in commercial activities, which will inevitably increase carbon dioxide emissions of commercial department.

The above results exert significant policy implications.

First, diverse measures are supposed to be applied to mitigate carbon dioxide emissions of commercial department in different phases of economic development. At the previous stages, electronic commerce, wholesale and retail trade usher a rapid growth. Hence, there is a large demand for commercial asset investment and infrastructure construction that will indirectly emit a great deal of carbon dioxide emissions in commercial department. Firstly, the ministries at all levels should guide the development of commercial department. For the purpose of abating the carbon dioxide emissions caused by

Table 4 Consequences of OLS regression

OLS result	Unstandardized coefficient	<i>t</i> statistic sig.	VIF
Constant	− 132.590	0.019	
lnGDP	0.613	0.003	1106.293
lnURB	0.045	0.964	2082.511
lnPOP	11.640	0.022	1231.950
lnEI	0.686	0.000	46.705
lnES	− 0.351	0.006	24.489
lnFDI	− 0.011	0.723	101.360
Adjusted <i>R</i> ²	0.999		
<i>F</i> statistic sig.	0.000		

commercial real estate expenditure and infrastructure construction, the government should vigorously improve and promote the economic structure. Meanwhile, the authorities are supposed to enhance fostering the service sector such as the e-commerce, Internet industry and information technology industries that possess low carbon dioxide emissions. Secondly, with further development in economy, energy-efficient building materials and commercial freight transportation of low energy were widely adopted. It will further mitigate the carbon dioxide emission intensity of commercial department.

Second, merchants should intensify research and adoption of low-carbon and environmental facilities, residents are supposed to promote the environmental awareness and usher green lifestyle. On the one hand, China is undergoing a rapid urbanization process. The scale of commercial enterprises will continue to amplify. The investigation and adoption of low-carbon and environmental technologies will be an essential method to mitigate carbon dioxide emissions of commercial department. Therefore, the commercial practitioners ought to exert more efforts in intensifying investigation and use of low-carbon and environmental technologies, such as low-carbon production equipment and energy-efficient building materials. On the other hand, further urbanization leads to vigorous growth of urban residents and their income, thereby, requiring massive commercial services and goods. So urban residents should promote the environmental awareness and embrace the green lifestyle.

Third, business practitioners should attach more importance to environmental protection, and the public also ought to foster

Table 3 Results of correlation test

	lnGDP	lnURB	lnPOP	lnEI	lnES	lnFDI
lnGDP	1					
lnURB	0.998**	1				
lnPOP	0.995**	0.999**	1			
lnEI	0.984**	0.975**	0.971**	1		
lnES	− 0.955**	− 0.952**	− 0.941**	− 0.955*	1	
lnFDI	0.991**	0.983**	0.978**	0.985*	− 0.962**	1

Note: ** significant at 5%, * significant at 10%

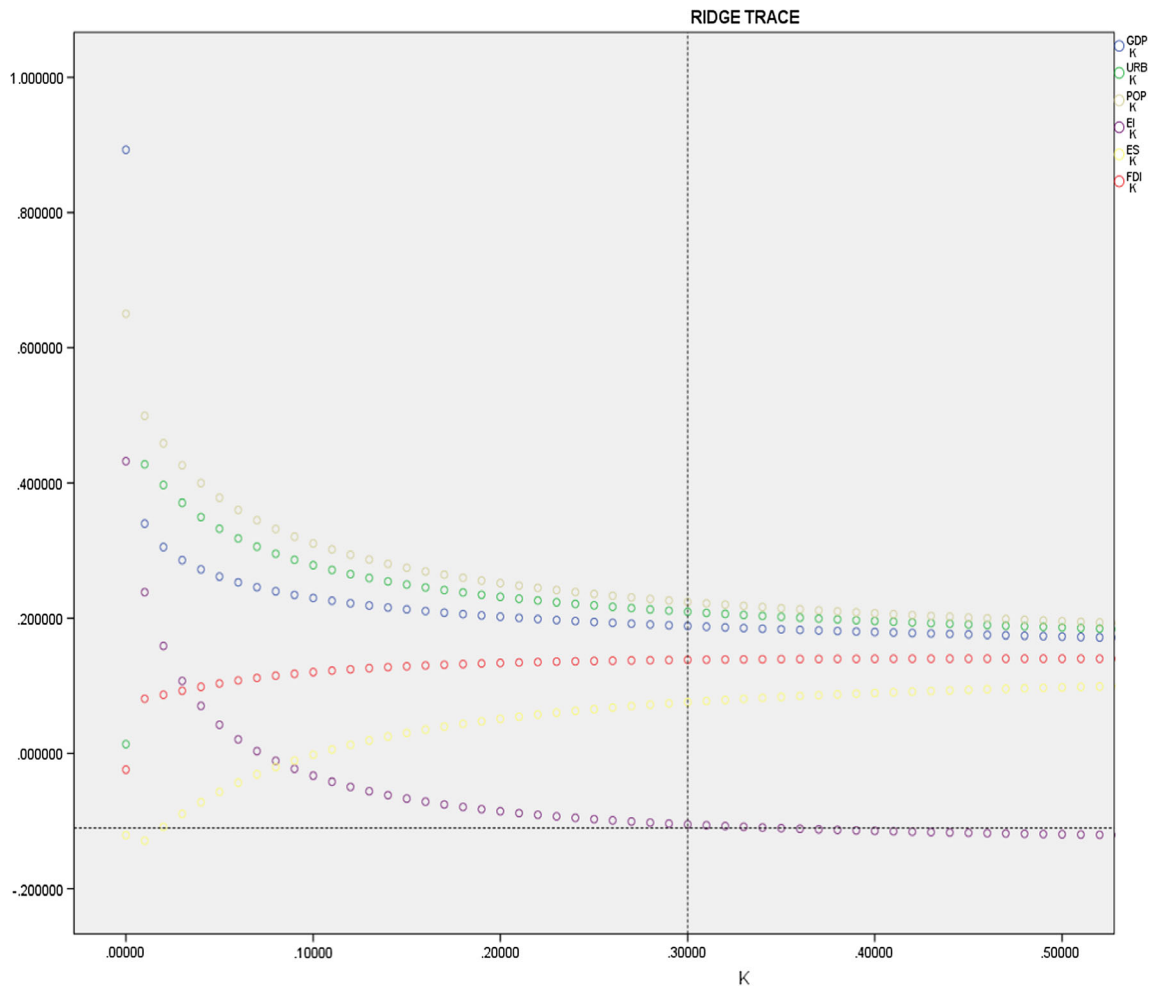


Fig. 2 Curves of ridge t race

Fig. 3 Changes of k under different RSQ

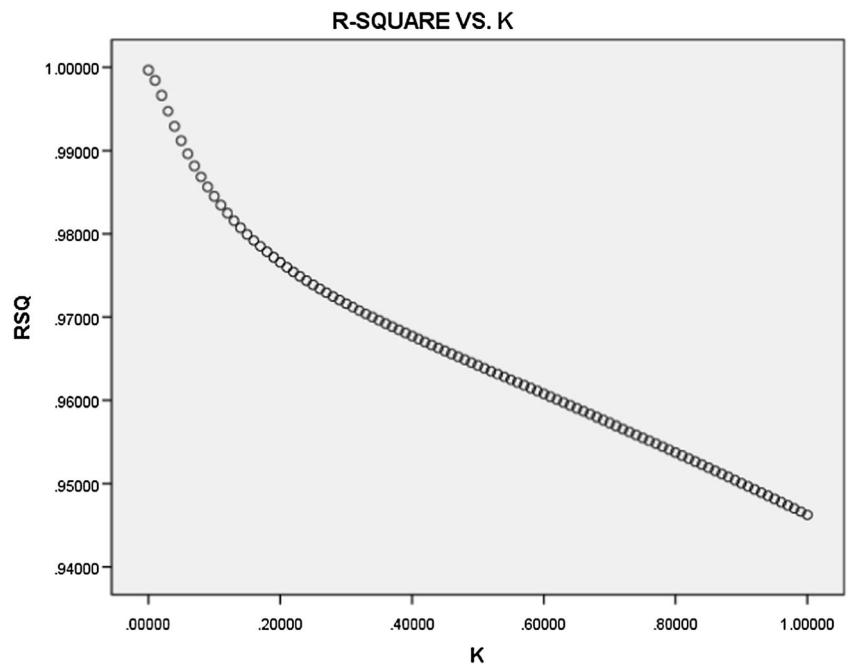


Table 5 Consequences of tests about all explanatory variates and constant

	Constant	lnGDP	lnURB	lnPOP	lnEI	lnES	lnFDI
Coefficient's <i>t</i> sig	−44.81***	0.13***	0.69***	4.01***	0.17***	−0.22*	0.06***

Note: *** significant at 1%, * significant at 10%

the green lifestyle. It is universally acknowledged that China has a population of 1.4 billion, and thus embraces a large consumer market as household income rises. Huge size of population will lead to a massive demand for commercial services and goods. In order to mitigate energy consumed and carbon dioxide emissions of commercial services and goods, the public should strengthen the environmental awareness and purchase low-carbon goods. The authorities should encourage consumers cultivate low-carbon lifestyle (Zeb et al. 2014). Meanwhile, as vital parts of commercial department, wholesale and retail trade, hotels and catering services industry embrace relatively high energy intensity than else commercial enterprises (Wang and Lin 2017). Hence, commercial practitioners should attach more importance to environmental protection. So commercial enterprises with low energy intensity, such as e-commerce and new retail, should be promoted, which is conducive to ameliorating the energy efficiency of the total commercial department. Finally, in order to make the utmost of the scale effect and promote the energy efficiency, annexation and recombination ought to be promoted in commercial department.

Fourth, business practitioners and authorities are supposed to initiate flexible and feasible talent and technology policies to efficiently abate energy consumed and carbon dioxide emissions of commercial department. Low-carbon and environmental technologies are laggard in China. For the sake of restraining the swift increase of carbon dioxide emissions, the business practitioners ought to bring in advanced energy-saving and low-carbon technologies and facilities. Meanwhile, government should stimulate the business practitioners and related research institutions to amplify the scale of research and development expenditure and research and development personnel investments. In the long run, energy-saving and low-carbon technology researches ought to be further intensified. For the sake of promoting energy efficiency and mitigating carbon dioxide emissions, government should enhance the low-carbon and environmental technologies applying fiscal and monetary policies, for instance stimulating relevant commercial enterprises to exert more efforts in research and development of low-carbon technologies by relevant favourable policies. It will be conducive to fostering massive high-level personnel about environmental protection.

Finally, the authorities at all levels ought to guide the commercial practitioners to ameliorate energy structure and enhance the usage of gas and clean electricity such as solar energy, wind energy and hydroelectric. For the time being, massive thermal power consumed brings about energy structure generating an affirmative influence on carbon dioxide

emissions of commercial department. Low-carbon and environmental technologies will be hard to acquire noticeable improvement in the short run. Thereby, government at all levels should stimulate commercial practitioners to augment the use of gas and clean electric power, and gradually reduce thermal power consumption. In order to satisfy clean electric power demand and abate carbon dioxide emissions, the government of China has planned to vigorously develop wind power and solar energy in eastern coastal and western regions. In the meantime, the authorities should vigorously exert more efforts in exploiting the huge potential of hydropower resources in Sichuan and Yunnan provinces. Thirdly, about half of the coal is consumed by hotels and catering services enterprises, wholesale and retail trade enterprises department for heating in the commercial. For the sake of abating coal consumption, gas heating and central heating systems should be introduced to commercial department.

Despite the merits demonstrated in the study, some limitations are still worthy of further study. First, it exists significant differences in distribution of natural resources and the level economic development in China owing to its vast territory. Thus, the carbon dioxide emissions of commercial department are impacted by regional traits. At the same time, urbanization, aggregate population and technological development level, and foreign direct investment also vary in different regions. This paper investigates the driving forces of carbon dioxide emissions of commercial sector from a national view ignoring regional differentiation. Based on above analysis, in future study, we will research the factors influencing carbon dioxide emissions from a regional viewpoint. Second, other potential factors, such as the degree of aggregate export contribution to GDP, are not incorporated in our paper. These factors may also exert important impacts on carbon dioxide emissions of commercial department; however, with a view to the scope of this paper, an in-depth exploration of these links will be beyond. Hence, we can research the impact of above driving factor is China's commercial department.

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