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Do New Energy Vehicles Really Reduce Carbon Emissions? -An Empirical Analysis of Panel Data from Prefecture-level Cities in China

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Abstract: As one of the key strategic areas to promote sustainable development, the development of new energy vehicles is crucial to alleviate environmental pressure and energy challenges. Based on an in-depth analysis of the actual use of new energy vehicles, China's electricity supply system and carbon emission mechanisms, the paper collects and collates data from the key provinces and cities for the promotion of new energy vehicles mentioned in the 2016 Notice on the "13th Five-Year" New Energy Vehicle Charging Facility Incentive Policies and Strengthening of New Energy Vehicle Promotion and Application, and applies the dual The empirical analysis is carried out using the double splitting method to quantitatively assess the carbon emission impacts of the promotion of new energy vehicles, and the final conclusion is that under China's existing energy structure, the promotion of new energy vehicles will not effectively reduce carbon emissions, but rather contribute to the further growth of carbon emissions. Moreover, the paper attempts to predict that with the continuous optimisation of the energy structure, China may reach the carbon equilibrium point by 2033 through the promotion of new energy vehicles, thus truly achieving the theoretical carbon reduction effect of new energy vehicles. Therefore, the government needs to flexibly adjust the promotion strategy of new energy vehicles to adapt to the power production structure and supply and demand situation in different regions, so as to maximise the carbon emission reduction benefits of promoting new energy vehicles under the existing energy structure; at the same time, it should actively promote the policy of optimising the energy structure, so as to make the carbon emissions reach the carbon equilibrium point under the context of promoting new energy vehicles, and to truly make new energy vehicles become an effective tool for promoting carbon emission reduction. The thesis provides some practical guidance for governmental decision- making in the fields of energy structure reform, carbon emission reduction and new energy vehicle development, and has certain decision-making reference significance.

Keywords: Carbon emission reduction, promotion of new energy vehicles, energy mix.

1. Introduction

China has made the realization of carbon peaking and carbon neutrality an important commitment in its response to climate change and global climate governance, a commitment that is not only a layout at the national strategic level, but also a profound change at the economic and social levels. Energy consumption, especially in transportation, has a decisive impact on carbon emissions. China's transportation sector accounted for a notable share of the country's total energy consumption in 2019, up to 10 percent, according to the latest data revealing. New energy vehicles, one of the key means to reduce carbon emissions, have received great attention from the government in China. The government regards the new energy vehicle industry as a strategic emerging industry and has accelerated its technological research and development, production investment and market expansion by implementing a series of incentive policies. These measures have achieved remarkable results, enabling China's sales of new energy vehicles to jump to the forefront of the world and steadily increase their market share. However, the promotion of new energy vehicles has increased electricity consumption while reducing carbon emissions during driving. Under the current structure of electricity production, whether new energy vehicles have truly contributed to the reduction of carbon emissions in the whole society requires further in-depth research and discussion.

Therefore, the thesis analyzes the specific impact of the promotion of new energy vehicles on regional carbon emissions by using the double- difference method with new energy vehicle promotion cities in China's public service sector as a case study. The thesis not only combines the marketing of new energy vehicles with regional carbon emissions to provide empirical support for the carbon emission reduction effect of new energy vehicles under the current power structure, but also accurately identifies the net effect of new energy vehicle promotion policies on regional carbon emissions. In addition, the paper emphasizes the importance of transforming the electricity production structure to a cleaner and greener direction, which provides a valuable reference basis for relevant policy formulation.

2. Literature Review

Although the former scholars have more in- depth knowledge of the carbon emission reduction benefits of new energy vehicles in terms of energy consumption and gas emissions, there are still discrepancies in some of the studies conducted by various scholars. Some scholars believe that although the existing energy structure in China has an impact on the carbon emission reduction strength of new energy vehicles, the overall level of carbon emissions is still lower than that of traditional fuel vehicles. For example, Fu Pei et al. built their own whole life cycle carbon emission evaluation model for ICEV, MHEV, HEV, BEV and FCV (the model includes vehicle production, vehicle assembly, operation and use, and end-of-life), drawing on the models accumulated by previous scholars. (the model includes whole vehicle production, whole vehicle assembly, operation and use, and end-of-life recycling carbon emission evaluation model), and concluded that BEVs have significant carbon reduction benefits compared with ICEVs in the whole life cycle[5]. Some scholars believe that the carbon emissions of new energy vehicles in the whole life cycle are greatly affected by the energy structure, and that carbon dioxide generated from power generation is not less than that from fuel vehicles, and it is necessary to optimize the energy structure continuously to achieve the theoretical carbon reduction benefits of new energy vehicles. It is necessary to optimize the energy structure in order to realize the theoretical carbon emission reduction benefits of new energy vehicles. Estimates of CO_2, SO_2, and NOx emissions from electric vehicles in the fuel cycle in China today (2008) and in the future (2030) by experts such as Hong Huo and others, as well as studies comparing traditional gasoline vehicles with gasoline hybrids, point to the result that, when relying on the existing grid for recharging, electric vehicles may emit 3 to 10 times more sulfur dioxide (SO_2) than gasoline vehicles, and the emissions may increase 3 to 10 times more than gasoline vehicles. emissions are likely to increase by a factor of 3 to 10 and NOx emissions will double compared to gasoline vehicles. As future thermal power plants adopt more advanced emission controls, NOx emissions from EVs are expected to equal those of gasoline vehicles, but SO_2 emissions will still increase. That is, the advantage of electric vehicles in reducing CO_2 emissions is not significant. It is emphasized that although electric vehicles provide an effective way to solve problems such as oil shortage in China, the environmental problems that may be brought about by their use should not be ignored[13].

Although the core references utilize a similar methodology, the policy starting point of the study is 2009, the beginning of the development of new energy vehicles, the whole society is still at a low level of ownership, and the study of the impact of new energy vehicles on carbon emissions may lack a certain degree of accuracy[4]. The paper will use the latest data to conduct a new round of discussion on this issue, based on the 2016 *'13th Five-Year' new energy vehicle charging facilities incentives and to strengthen the new energy vehicle promotion and application of the notice* mentioned in the vigorously promote new energy vehicle application of provincial and municipal data to carry out the research and analysis, from the new energy vehicles really began to explosive growth stage divided into time nodes, set the experimental time to analyze the impact of new energy vehicles on carbon emissions. The study analyzes the data from the provinces and cities mentioned in the notice on the '13th Five-Year' new energy vehicle charging facility incentive policy and strengthening the promotion and application of new energy vehicles to carry out the research and analysis, and divides the time nodes from the stage of new energy vehicles really starting to explode to the stage of growth, sets up experimental groups and control groups, and employs double-difference method for empirical demonstration.

3. Theoretical Assumptions of the Impact of New Energy Vehicle Promotion on Carbon Emissions and the Construction of the Model

3.1. Theoretical Assumptions on the Impact of the Promotion of New Energy Vehicles on Carbon Emissions

When examining the potential environmental impacts of new energy vehicles, from a theoretical perspective, their replacement of traditional fuel vehicles has significant potential for reducing carbon emissions in the transportation sector, and this view is widely shared in the academic community. Because new energy vehicles use electricity as their power source, the process of their use itself does not produce pollutants or harmful gases, and therefore, theoretically, they have a positive effect on reducing carbon emissions.

However, from the perspective of the full life cycle theory, despite the fact that electric vehicles reduce pollutant emissions during the driving process, under China's power structure, which is dominated by thermal power generation, the effect of new energy vehicles in reducing carbon emissions is not significant. They actually only transfer pollution emissions from the transportation sector to the power production sector. Because the promotion of new energy vehicles increases the demand for electricity, it may lead to an increase in thermal power generation, which in turn increases the amount of coal burned, so from the perspective of the whole process of energy consumption, 'driving with electricity' is actually transformed into 'driving with coal'. Therefore, experts pointed out that the promotion of new energy vehicles must be accompanied by the decarbonization process of electricity production, in order to truly realize the reduction of the transportation sector's dependence on oil, and help reduce carbon dioxide emissions.

In summary, the thesis hypothesizes that the promotion of new energy vehicles may actually increase carbon emissions at the current stage when electricity production has not been 'decoupled from carbon'.

3.2. Model construction of carbon emissions affected by the promotion of new energy vehicles

In 2016, the Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, the Development and Reform Commission, and the National Energy Administration jointly issued the "Incentive Policies on Promoting the Construction of New Energy Vehicle Charging Facilities and the Popularization and Application of New Energy Vehicles during the 13th Five- Year Plan Period," which provides a basis for the paper to analyze the impacts of the promotion of new energy vehicles on regional carbon emissions by using the double-difference method. Therefore, the paper chooses to use the double- difference method to analyze the impact of the promotion of new energy vehicles on regional carbon emissions. Therefore, the model is constructed as follows:

$$\text{totalcarbondioxide} = \beta_0 + \beta_1 \text{did} + \sum_j \beta_j * \text{Control} + \gamma_t + \mu_i + \varepsilon_{it}$$

The explanatory variable totalcarbondioxide is the total apparent carbon dioxide emissions of each prefecture-level city, representing the level of carbon emissions, with the subscript i denoting the ith city, and the subscript t denoting the tth year. did represents the cross-multiplication of the promotion of new energy vehicles in key cities with time (i.e. the policy dummy variable). The article focuses on the coefficient β_1, which represents the net policy effect of promoting new energy vehicles on regional carbon emissions. Control is the control variables, including the annual sales volume of new energy vehicles, the urbanization level of the population, the population size, the added value of the tertiary industry, the investment in environmental pollution control, the end-of-year financial institutions' loans in RMB, and the level of social consumption. γ_t denotes the time fixed effect and μ_i denotes the regional fixed effect.

4. Test and Analysis of The Empirical Results of The Impact of The Promotion of New Energy Vehicles on Carbon Emissions

4.1. Descriptive statistics

The descriptive statistics of the main variables are shown in the following table (Table 4.1). The standard deviation of carbon dioxide emissions is 2829.418, which indicates that the degree of dispersion of each prefecture-level city is high due to the level of urban development, energy structure, population size and other factors.

Table 4.1 Descriptive statistics regression results

Variable	Obs	Mean	Std. Dev.	Min	Max
co2	3089	3424.998	2829.418	762.96	58281
did	3089	.293	.455	0	1
sal	3089	1440.259	4968.606	0	40263
consum	3087	0	0	0	0
popula	3087	5.881	.67	3.664	7.215
indus	3089	12339.796	11044.297	468.2	54710.4
loans	3087	30760945	54984034	1559494	3.950e+08
inve	3089	31.396	25.763	1.29	545.2
urban	3072	.553	.149	.252	.947

4.2. Correlation analysis and multicollinearity test

The following table (Table 4.2) shows the correlation analysis of the explanatory variables, and the correlation coefficients of all the explanatory variables are almost less than 0.8, which indicates that there is no strict multicollinearity between the variables. co2 is positively correlated with did, which is in line with the thesis' basic hypothesis, i.e., probably due to China's coal-dominant energy structure, the new energy vehicles'

The promotion of new energy vehicles does not realize carbon emission reduction, but only transfers carbon emissions from the end to the front of the life cycle of new energy vehicles. The positive correlation between carbon dioxide emissions and the sales of new energy vehicles also shows that the increase in the sales of new energy vehicles increases carbon emissions, i.e., the widespread use of new energy vehicles does not have a positive impact on carbon reduction.

Table 4.2 Correlation analysis regression results

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) co2	1.000								
(2) did	0.133*	1.000							
	(0.000)								
(3) sal	0.260*	0.343*	1.000						
	(0.000)	(0.000)							
(4) consum	-0.106*	-0.272*	-0.209*	1.000					
	(0.000)	(0.000)	(0.000)						
(5) popula	0.172*	0.218*	0.236*	-0.589*	1.000				
	(0.000)	(0.000)	(0.000)	(0.000)					
(6) indus	0.127*	0.587*	0.345*	-0.355*	0.275*	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)				
(7) loans	0.361*	0.240*	0.738*	-0.344*	0.357*	0.328*	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(8) inve	0.862*	0.205*	0.302*	-0.106*	0.183*	0.266*	0.394*	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(9) urban	0.196*	0.248*	0.336*	-0.237*	-0.199*	0.298*	0.521*	0.250*	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

In addition, the thesis continued to do a vif test, and as shown in the table below (Table 4.3), the vif values of each explanatory variable are less than 8, which again confirms that there is no significant multicollinearity between the core explanatory variables and each of the control variables.

Table 4.3 Results of vif test

	VIF	1/VIF
loans	3.846	.26
popula	2.896	.345
urban	2.523	.396
sal	2.472	.405
consum	2.127	.47
indus	1.735	.577
did	1.647	.607
inve	1.237	.808
Mean VIF	2.31	

4.3. Benchmark multiple regression analysis

Through the F-test and Hausmann test, the thesis is based on the *'13th Five-Year' new energy vehicle charging facilities incentives and to strengthen the promotion and application of new energy vehicles in the notice* in the promotion of new energy vehicles since 2016 in the city data, select the fixed-effects model into the empirical analysis, the baseline regression results are shown in the following table (Table 4.4).

First, model (1) regression of control variables and explanatory variables, from the table easy to know that the regression coefficient of the sales of new energy vehicles is positive, the t-statistic is 4.808, which is significant at the 1% level, indicating that the higher the sales of new energy vehicles, the higher the carbon dioxide emissions. Model (2) after adding the core explanatory variable did, the regression coefficient of did is positive 110.755, and it is significant at 1% level, meanwhile, the correlation and significant level of other variables are basically unchanged, which indicates that the popularization and use of new energy vehicles positively increase carbon emissions in various places to a greater extent, and it can initially confirm the thesis hypothesis that: in China's energy structure is still dominated by coal power generation and it is difficult to transform it in the short term, the new energy vehicles will be the main source of energy for the country. It can initially confirm the thesis hypothesis that the popularization of new energy vehicles does not effectively promote the realization of carbon emission reduction goals in China, where the energy structure is still dominated by coal power generation and it is difficult to be changed in the short term, and that the carbon emission of new energy vehicles is only shifted from the PTW (Pump to Well) stage to the WTP (Well to Pump) stage of the whole life cycle, and does not produce a significant reduction.

Table 4.4 Benchmark multiple regression results

	(1)	(2)
	co2	co2
did		110.755***
		(3.841)
sal	0.010***	0.009***
	(4.808)	(4.382)
consum	-4.96e+06	-4.59e+06
	(-1.643)	(-1.526)
popula	-13.075	-13.940
	(-0.763)	(-0.815)
indus	-0.000	-0.004*
	(-0.170)	(-1.928)
loans	0.000***	0.000***
	(4.915)	(5.202)
inve	12.393***	12.410***
	(20.608)	(20.683)
urban	-206.517***	-215.834***
	(-2.800)	(-2.931)
_cons	2801.664***	2826.801***
	(20.670)	(20.878)
time effect	Control	Control
regional effect	Control	Control
N	3070	3070
R^2	0.549	0.551
F	204.470	195.366

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

4.4. Robustness Tests

4.4.1. Replacement of explanatory variables

Considering that in addition to carbon dioxide, the pollutants emitted by automobiles also mainly contain $PM_{2.5}$, which will cause obvious adverse effects on urban air quality as well as the green development environment. Therefore, the thesis replaces the explanatory variable with $PM_{2.5}$ to test the relationship between the popularization and use of new energy vehicles and $PM_{2.5}$ emissions. In this case, $PM_{2.5}$ was obtained from publicly available data published by the

Atmospheric Composition Analysis Group at Washington University in St. Louis (formerly Dalhousie University). Model (2) in the following table (Table 4.5) shows that the promotion of the use of new energy vehicles still has a positive and significant effect (at the 1% level) on $PM_{2.5}$ emissions. That is, there is a positive and significant relationship at the 1% level between the promotion and use of new energy vehicles on both CO_2 emissions and $PM_{2.5}$ emissions. Therefore, it can be proved that the conclusions of the underlying regression of the paper are robust.

Table 4.5 Regression results before and after replacing the explanatory variables

	(1) co2	(2) pm25
did	364.718***	4.060***
	(4.272)	(5.676)
sal	-0.000	0.000
	(-0.048)	(0.730)
consum	-3.46e+07***	-6.69e+05***
	(-3.276)	(-7.555)
popula	-57.604	6.920***
	(-0.882)	(12.640)
indus	-0.035***	-0.000***
	(-11.209)	(-4.035)
loans	0.000***	-0.000***
	(3.358)	(-4.484)
inve	96.772***	0.018*
	(89.240)	(1.928)
urban	-395.617	2.698
	(-1.465)	(1.193)
_cons	1298.953***	2.254
	(2.592)	(0.537)
time effect	Control	Control
regional effect	Control	Control
N	3070	3070
R^2	0.759	0.210
F	1199.816	101.599

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

4.4.2. Parallel trend hypothesis and dynamic effects

The did empirical method requires that the explanatory variables in the experimental group and the control group have a similar development trend before the implementation of the policy, and if the trend is not similar, then it indicates that there are other factors that can significantly affect the explanatory variables before the implementation of the policy. That is, before the implementation of the new energy vehicle promotion policy, there is no systematic difference in carbon dioxide emissions between promoted and non-promoted cities, and if there is no impact of the new energy vehicle promotion policy, the trend of carbon emissions will converge in promoted and non-promoted cities.

Therefore, the paper draws on the de-meaned parallel trend test of former scholars[15] and draws a parallel trend graph of the impact of the new energy vehicle promotion policy on carbon dioxide emissions as shown in the following figure (Figure 4.1). From the figure, it can be seen that the trend of change before 2016 are not significant, and there is a slight downward trend, while after the implementation of the policy is obviously a stable growth trend, and all other results are significant except post_1 period. It shows that although there may be a certain lag in the effect of the policy in 2017, the carbon emissions in the promoted areas have undergone a significant increase in the next four years. In summary, it can be said that this new energy vehicle promotion policy passed the parallel trend test, which proves that it is reasonable for the paper to choose the data of the city where the policy is promoted and use the double difference method to test the relationship between the promotion of new energy vehicles and regional carbon emissions.

4.4.3. Placebo test

Considering that the statistical significance of the promotion and application of new energy vehicles on the regional CO_2 emission index may come from some unobserved random factors, the thesis conducts a placebo test to examine whether the effect of the promotion of new energy vehicles on the regional carbon emissions comes from other unobserved random factors. According to the data of new energy vehicle promotion cities in the ‘Notice on Incentive Policies for New Energy Vehicle Charging Facilities in the 13th Five-Year Plan and Strengthening the Promotion and Application of New Energy Vehicles’, the thesis randomly selects 123 data for the experiment and repeats the randomized test process for 500 times, and according to the experimental results the estimated coefficients of the dids are plotted into a distribution graph (Fig. 4.1). distribution graph (as shown in Figure 4.2). As can be seen from Figure 4.2, the estimated coefficients of the model roughly conform to the normal distribution centered on 0, i.e. the estimated coefficients are centrally distributed around 0, which indicates that the setup of the present model does not omit the unobserved random factors, and passes the placebo test. From this, it can be concluded that the regression test underlying the previous section of the article is robust and that the promotion of new energy vehicles does significantly increase regional carbon emissions.

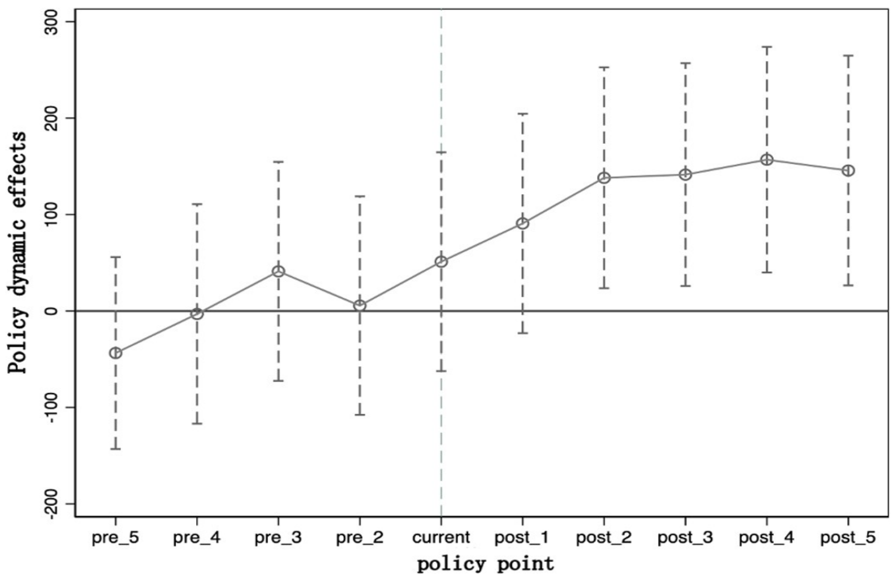

Figure 4.1 Plot of the results of the parallel trend test

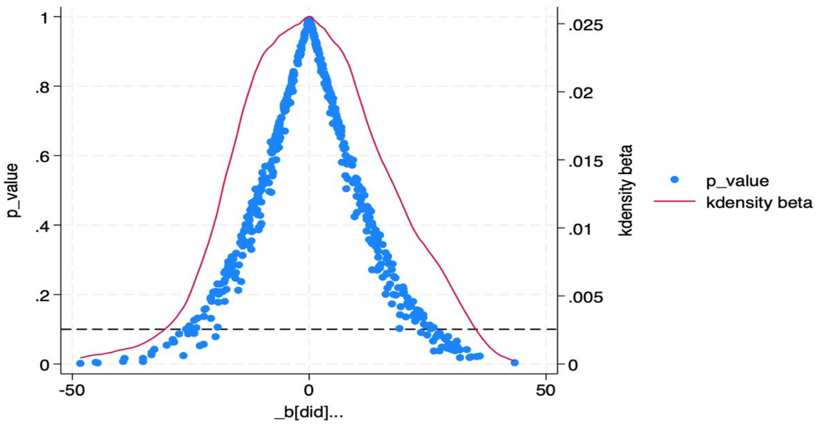

Figure 4.2 Plot of placebo test results

4.5. Heterogeneity test

4.5.1. Share of coal power generation

After the theoretical discussion and empirical data support in the previous section, it can be known that the promotion of new energy vehicles in China does not have a significant effect in reducing regional carbon emissions, and the core reason for this is that China's current power generation structure is still highly dependent on thermal power generation, which relies on a large amount of fossil energy and therefore produces more carbon emissions. In order to reveal this phenomenon more concretely, the paper, based on existing studies[4], compares the coal power generation share (except Hong Kong, Macao, Taiwan, and Tibet) of 30 Chinese provinces (autonomous regions and municipalities directly under the central government) with the national average in 2021 and divides them into two groups: 19 provinces with coal power generation share higher than the average and 11 provinces lower than the average, and the results of the division are shown in Table 4.6.

Table 4.6 Breakdown of provinces where the share of coal in power generation is above and below the national average

Cities where the share of thermal power is higher than the national average	Shanghai, Tianjin, Beijing, Anhui, Shandong, Shaanxi, Henan, Jiangxi, Jiangsu, Heilongjiang, Inner Mongolia, Hubei, Xinjiang, Ningxia, Jilin, Guangdong, Zhejiang, Chongqing
Cities where the share of thermal power is lower than the national average	Liaoning, Hainan, Guizhou, Hunan, Fujian, Guangxi, Gansu, Hubei, Qinghai, Sichuan, Yunnan

By testing these two sets of data, the results are shown in Table 4.7. The data in Table 4.7 clearly show that the promotion of new energy vehicles largely increases carbon emissions in those regions with a higher share of coal power generation and has a significant negative effect on regions with a lower share of thermal power generation. This result further underscores that to realize the carbon reduction potential of new energy vehicles, China must step up its efforts to implement actions to optimize the energy mix for power generation. To realize the carbon reduction potential of new energy vehicles, China must increase its efforts to implement actions to optimize the energy mix of power generation, promote the unbundling of power generation from fossil fuels, reduce dependence on fossil fuels, and develop a cleaner, low-carbon energy mix.

Table 4.7 Regression results of heterogeneity test for cities with above and below mean share of thermal power generation

	(1)	(2)
	co2	co2
did	143.240***	-124.930***
	(3.680)	(-3.386)
sal	0.012***	-0.001
	(4.055)	(-0.596)
consum	-4.79e+05	-8.24e+06**
	(-0.117)	(-2.297)
popula	-8.375	-3.804
	(-0.328)	(-0.224)
indus	-0.006**	0.008***
	(-2.204)	(3.638)
loans	0.000***	0.000
	(4.904)	(0.186)
inve	17.278***	1.236*
	(20.410)	(1.896)
urban	-225.893**	-131.457
	(-2.260)	(-1.507)
_cons	2665.629***	2961.042***
	(13.478)	(20.991)
time effect	Control	Control
regional effect	Control	Control
N	1896	1128
R^2	0.550	0.731
F	119.423	156.985

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

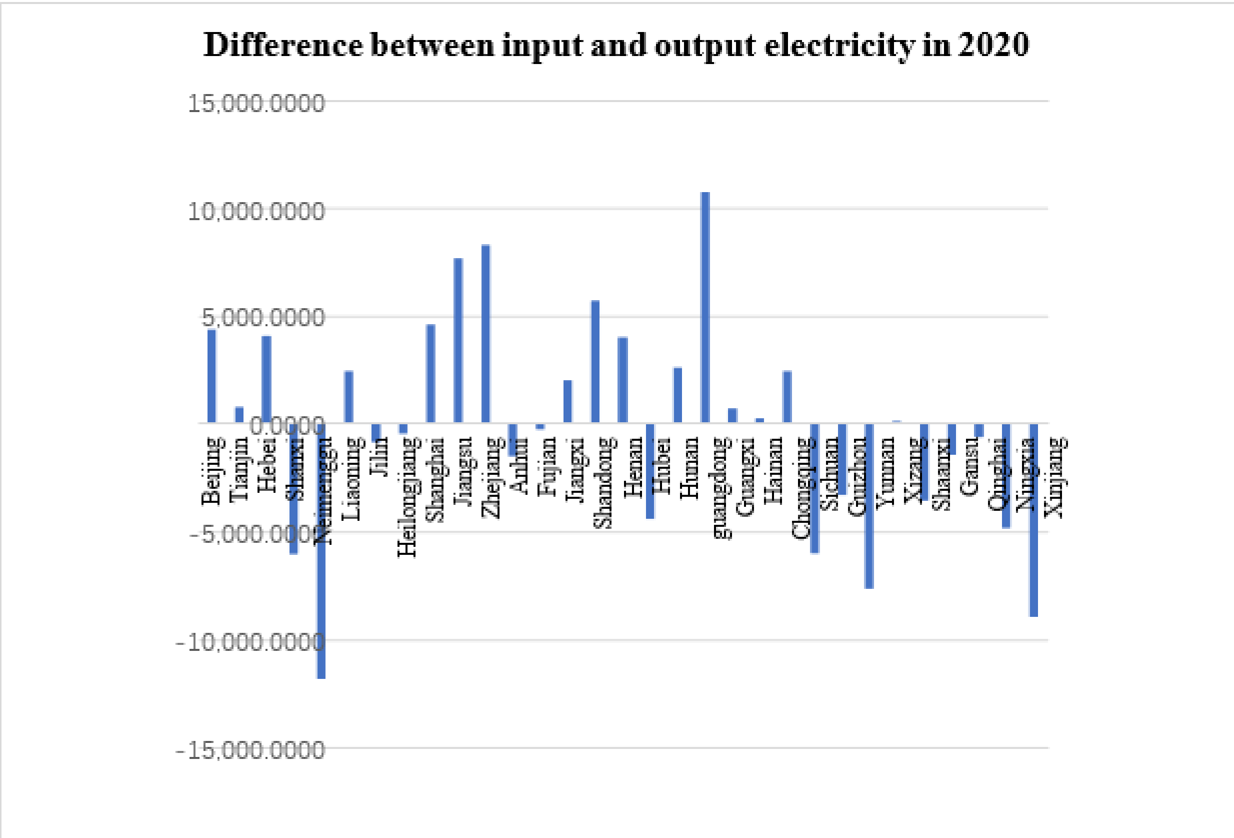

Figure 4.3 Plot of the results of calculating the difference between input and output electricity in 2020

4.5.2. Electricity Importing and Exporting Areas

The imbalance in the level of economic development and distribution of energy resources in various regions of China has led to significant differences in the supply and demand of electricity in different regions. Specifically, the more economically developed regions often face a tight power supply situation, while the central and western regions, despite their relatively lagging economies, often have a surplus of power supply due to their abundant energy resources. This imbalance not only affects the supply and demand of electricity in each region, but also has an impact on the relationship between the promotion of new energy vehicles and carbon emissions.

In order to analyze this issue more specifically, the paper calculates the electricity supply and demand gap of 30 provinces (autonomous regions and municipalities directly under the central government) in the country based on the data of 2020. The results are shown in Fig. 4.3, with 15 provinces whose electricity demand exceeds their generating capacity, mainly concentrated in economically developed areas along the eastern coast; while the other 15 provinces show electricity supply surpluses, mainly located in the economically relatively lagging but resource-rich inland areas of the central and western regions.

Based on this, the thesis categorizes the study promoted cities into two types according to electricity supply and demand: electricity exporting cities that are self-sufficient in electricity and electricity importing cities that are dependent on foreign provinces, and examines them separately. The results show (see Table 4.8) that the promotion of new energy vehicles does not have a significant impact on carbon emissions in cities that are self-sufficient in electricity; however, in cities that are dependent on the export of electricity, the promotion of new energy vehicles significantly increases carbon emissions.

This finding suggests that in regions that rely on electricity import, the demand for electricity is high but the supply is insufficient due to a more developed economy but limited natural resources. In order to make up for the shortfall, the installed capacity of local power generation is being increased in addition to the power imported from other regions. As a result, the promotion of new energy vehicles has led to an increase in thermal power generation in regions where the demand for electricity exceeds the supply, which in turn has increased their carbon emissions.

Table 4.8 Heterogeneity regression results for electricity consumption input and output locations

Continue Table 4.8 Heterogeneity regression results for electricity consumption input and output locations

	(1)	(2)
	co2	co2
did	236.356***	-50.516
	(5.410)	(-1.404)
sal	0.019***	-0.011***
	(6.730)	(-3.337)
consum	-3.71e+06	-3.53e+06
	(-0.669)	(-1.094)
popula	-70.882***	84.399***
	(-2.833)	(3.655)
indus	-0.007***	0.016***
	(-2.592)	(3.222)
loans	0.000***	0.000***
	(3.009)	(3.738)
inve	14.255***	8.552***
	(15.597)	(11.766)
urban	-330.483***	-1.700
	(-2.763)	(-0.019)
_cons	3195.822***	2184.522***
	(15.157)	(12.632)
time effect	Control	Control
regional effect	Control	Control
N	1776	1294
R^2	0.532	0.644
F	104.080	120.020

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

4.5.3. West-East Power Transmission Region

The core power of new energy vehicles originates from electricity, and the main source of electricity in China is still thermal power generation. According to statistics, thermal power generation will account for about 68% of China's power structure in 2021. Given the geographical distribution of China's fossil energy resources, which is characterized by a lack of energy in the east and a wealth in the west, China has launched the ‘West-to-East Electricity Transmission’ project since 2000. The purpose of this major project is not only to relieve the pressure on power supply in the economically developed eastern regions, but also to promote the effective development and utilization of the abundant power resources in the western and southwestern regions through the cross-regional deployment of power. This strategic initiative not only promotes the balanced development of regional economy, but also provides cleaner and more stable power support for the promotion of new energy vehicles. Based on the existing studies, the paper divides the samples according to the flow direction of 'West-East Electricity Transmission' into two major regions of input and output, as well as three specific corridors in the north, center and south, as shown in Table 4.9[16].

Table 4.9 West-East Power Transmission Regional Divisions

Corridors	Output region	Input region
Northern Corridor	Inner Mongolia, Shanxi, Shaanxi, Ningxia, Qinghai, Xinjiang, Gansu	Beijing, Tianjin, Hubei, Shandong, Liaoning
Southern Corridor	Yunnan, Guizhou, Guangxi	Guangdong, Hainan
Middle Corridor	Hubei, Sichuan, Chongqing	Shanghai, Jiangsu, Zhejiang, Fujian

Further, detailed regression analyses were conducted for the two major regions of input and output of the 'West-East Electricity Transmission' project as well as the three specific corridors in the north, central and south, and the results are summarized in Table 4.10.

Table 4.10 Heterogeneity Tests for the West-East Transmission Region

	(1) co2	(2) co2	(3) co2	(4) co2	(5) co2	(6) co2
did	-111.395	42.678	1082.844**	150.960	-13.215	245.803**
	(-1.491)	(0.573)	(2.543)	(1.199)	(-0.128)	(2.376)
sal	-0.024***	0.005	0.008	-0.005	0.012	0.058***
	(-3.518)	(0.989)	(1.287)	(-1.219)	(1.395)	(6.894)
consum	8.76e+06	-3.63e+05	-2.20e+06	-1.89e+06	-4.81e+06	-8.14e+06
	(1.579)	(-0.080)	(-0.094)	(-0.193)	(-1.015)	(-0.660)
popula	131.911***	51.577*	-3.053	2.343	80.940*	-74.262
	(2.949)	(1.818)	(-0.048)	(0.068)	(1.892)	(-1.117)
indus	0.039**	0.030***	0.005	0.035***	-0.001	-0.005
	(2.544)	(3.949)	(0.196)	(6.163)	(-0.072)	(-0.333)
loans	0.000***	-0.000***	-0.000	0.000	-0.000	-0.000*
	(5.602)	(-2.840)	(-1.050)	(0.379)	(-1.364)	(-1.943)
inve	11.348***	2.482	-0.620	1.033	1.003	51.045***
	(10.639)	(0.880)	(-0.463)	(0.826)	(0.852)	(19.178)
urban	-88.106	146.167	72.313	89.968	76.204	-506.653
	(-0.644)	(1.172)	(0.269)	(0.475)	(0.467)	(-1.275)
_cons	1862.847***	1255.149***	3280.103***	2389.845***	2714.461***	2805.526***
	(5.905)	(5.680)	(5.845)	(8.086)	(8.425)	(4.881)
time effect	Control	Control	Control	Control	Control	Control
regional effect	Control	Control	Control	Control	Control	Control
N	614	340	233	360	271	430
R^2	0.670	0.526	0.790	0.726	0.765	0.739
F	62.905	18.482	44.437	49.962	42.669	60.767

Note: *, **, and *** indicate significant at 10%, 5%, and 1% significance levels, respectively.

Based on the analysis, the paper draws the following main conclusions:

First, for the northern corridor, as the results of model (1)(2), the promotion of new energy vehicles did not significantly increase the carbon emissions of the output or input regions. This may be mainly due to the fact that there are provinces like Qinghai and Gansu in the northern corridor that have a cleaner energy mix for power generation, so the increase in power output does not directly lead to an increase in carbon emissions.

In the South Corridor, as shown in the results of model (3) and (4), the promotion of new energy vehicles significantly increases carbon emissions in the exporting regions, but the effect on the importing regions is not significant. This may be due to the fact that the power output region increases the local power generation load due to the transmission of power to the power importing region, and its power structure dominated by thermal power generation does not have strong cleaning effectiveness, which ultimately increases the local carbon dioxide carbon emissions significantly.

Finally, for the middle corridor, as shown in the results of model (5)(6), the promotion of new energy vehicles has no significant effect on the carbon emissions of the output region, but has a significant positive effect on the power input place. This may be due to the fact that the input regions of the middle corridor, such as the southeastern coastal regions, have rapid economic development and high power demand, which requires local increase in installed power generation capacity in addition to the power imported from the west, and due to the geographic conditions, these regions rely more on thermal power generation. Comparatively speaking, the output areas of the Central Corridor have the advantage of natural conditions, such as Sichuan, which has good natural conditions for hydroelectric power generation and is able to build large-scale water conservancy projects (e.g. the Dujiangyan Water Conservancy Project), so the increase in electricity has not brought about a significant increase in carbon emissions.

In summary, in order to fully utilize the role of new energy vehicles in carbon emission reduction, China must first take the transformation of the power production structure as an important task, gradually reduce the dependence on thermal power generation and increase the proportion of clean energy.

5. Carbon Equilibrium Point Measurement of Carbon Emissions from New Energy Vehicles and Policy Recommendations

5.1. Measurement of the carbon balance point of carbon emissions from new energy vehicles

Under the current energy mix, the widespread application of new energy vehicles has not yet been able to fully realize their expected carbon reduction effectiveness. However, given the government's strong commitment and continuous efforts to achieve carbon neutrality and peak carbon goals, the energy mix is gradually shifting

towards a cleaner and more sustainable direction. The paper therefore attempts to predict the carbon equilibrium point, i.e., the point in time in the future when the promotion of new energy vehicles can achieve carbon emission reductions under the then-cleaner energy mix. 2008 marked an important starting point for China's new energy vehicle industry, with 500 domestic new energy vehicles displayed at the Olympic Games marking the beginning of the marketing phase of new energy vehicles. Subsequently, the promotion of new energy vehicles only started in the public service sector, such as public transportation, rental, public service, sanitation and postal service. Therefore, the paper simulates the carbon emissions from the transportation sector in the next 30 years when new energy vehicles have never entered the market by using the carbon emissions data of the transportation sector before 2008 when new energy vehicles have not yet entered the market and fuel vehicles have almost covered the whole society (the results are shown as the blue line). And then predicts the carbon emissions from the transportation sector in the next 15 years when new energy vehicles gradually take over the market by using the carbon emissions data of the transportation sector in the period up to 2023 when new energy vehicles have already entered the market and are widely popularized (the blue line). Secondly, using the current data of carbon emissions from the transportation sector by 2023, when new energy vehicles have already entered the market and become widely used, to predict the carbon emissions from the transportation sector in the next 15 years when new energy vehicles gradually take over the market (the result is shown as the orange line). As seen in Figure 5.1, the two projected lines intersect in 2033, and this intersection point is the carbon balance point, indicating that under the energy structure at this point, the promotion of new energy vehicles will begin to produce real carbon reduction benefits, and substantially contribute to the reduction of carbon dioxide emissions from the transportation sector.

This transition point indicates that, given the current pace of energy structure change, new energy vehicles may not be able to fully utilize their carbon reduction effect before the 2030 peak carbon target is achieved. However, in the long run, this change will have a significant and positive contribution to the achievement of the 2060 carbon neutrality target. What this finding means for governments is that more determined and sustained efforts are needed to promote energy mix optimization. If the government can further increase its efforts to accelerate the transformation of the energy mix, there is every reason to believe that the carbon emission reduction benefits of new energy vehicles may start to show up and contribute to the realization of the carbon neutrality target as early as 2033, or even before 2030.

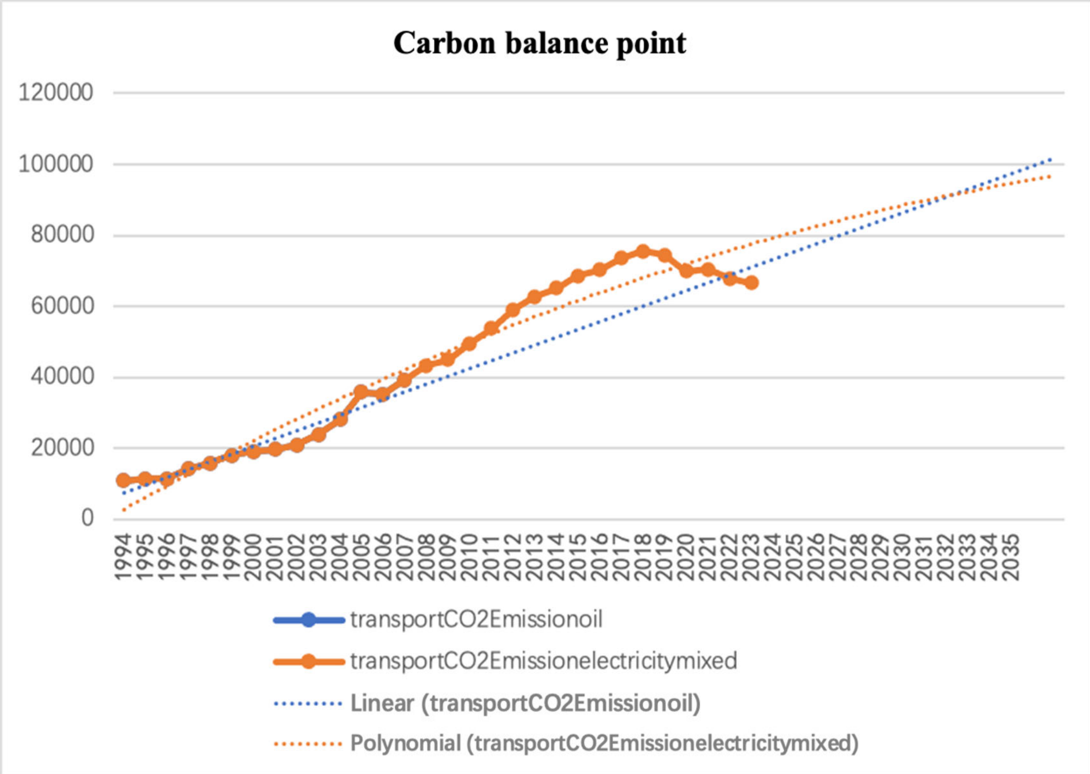

Figure 5.1 Carbon Balance Point Measurement Map

5.2. Policy Recommendations after the Carbon Balance Point is Measured

5.2.1. Continuously Promote the Optimization of Power Supply Structure

Obviously, new energy vehicles, as an important part of future sustainable transportation, cannot realize its carbon reduction effect without clean power supply. Therefore, building a low- carbon power production structure has become the core guarantee for the cleaner energy consumption. Government departments should make concerted efforts to actively promote the green transformation of the power generation energy structure to provide a solid energy foundation for the promotion of new energy vehicles.

In the new investment in regional power, the government should make clear the priority status of clean energy. For hydropower, wind power, nuclear power and other clean energy projects, more funds and policies should be tilted. At the same time, the proportion of investment in traditional energy projects such as gas power and coal power should be gradually reduced, lowering their proportion in the power structure.

5.2.2. Implementing Differentiated New Energy Vehicle Promotion Strategies

In areas where the energy mix is already relatively clean, government departments should actively promote new energy vehicles and encourage consumers to purchase and use them. In regions that are highly dependent on fossil energy for power generation and in traditional resource-based cities, the promotion strategy for new energy vehicles needs to be more prudent. The government should first focus on the low-carbon transformation of the power structure, and reduce carbon emissions in the power production process through the development of renewable energy and the improvement of energy efficiency. After the power structure has been significantly improved, new energy vehicles should be gradually promoted to ensure that their carbon emission reduction benefits are fully realized.

5.2.3. Achieving synergies among sectors to reduce interregional pollution transfer

Taking the West-East Power Transmission Project as aakn example, the project has played an important role in promoting regional economic development and optimizing resource allocation. However, the project will also bring certain challenges in the process of promoting new energy vehicles. The southern corridor region has experienced a sharp increase in power demand due to rapid economic development, and the power imported from the west has stimulated local power consumption while meeting these demands. This sustained growth in power consumption not only affects the stability of the energy structure of the power importing regions, but also makes these regions more dependent on thermal power generation.

Therefore, the government needs to optimize the industrial layout to avoid the over- concentration of high-pollution and high-energy- consumption industries in the region, and at the same time, strengthen the construction of the power transmission network to ensure a stable supply of green power. The government should actively prevent the “gradient transfer” of carbon emissions between supply chains and regions through regional linkages. This will require enhanced cooperation and exchanges between regions, the joint formulation of emission reduction targets and action plans, and the formation of regional carbon emission reduction alliances.

6. Conclusion

The paper focuses on the impact of the popular use of new energy vehicles on carbon emissions and its mechanism of action. By analyzing the panel data of prefecture-level cities participating in the promotion of new energy vehicles in China during the period from 2010 to 2021, the paper uses the double-difference method to explore in depth the actual effect of the promotion of new energy vehicles on carbon emissions. The empirical results of the paper reveal that the current power structure in China is not yet sufficient to fully support the potential of new energy vehicles in energy saving and emission reduction. Thermal power generation still accounts for a significant portion of the energy consumption of new energy vehicles, which results in the transfer of carbon emissions that would otherwise be reduced during driving to the power generation sector, making electric vehicles essentially ‘coal-driven’ vehicles. This finding remains significant after various robustness tests, including the replacement of explanatory variables, parallel trend tests, and placebo tests, highlighting the critical importance of a green transformation of the electricity mix in achieving the carbon emission reduction targets of new energy vehicles.

In view of the high consumption of electricity by new energy vehicles, the dissertation analyzes the heterogeneity according to the conditions of coal share, electricity supply and demand, and the transmission and distribution region of ‘West- East Power Transmission’, which can more accurately reflect the impact of electricity consumption on carbon emissions under different energy structures. The results of the analysis show that the promotion of new energy vehicles in the thermal-dominated power importing regions actually exacerbates the carbon emissions in the region, while the effect is not significant in the clean energy-dominated power exporting regions. This result confirms the strong link between energy mix and the carbon reduction effect of new energy vehicles. Divided by power supply and demand, the analysis concludes that the power importing region has a high demand for power resources due to its rapid economic development, thus increasing the installed capacity of local power generation in addition to the power imported from the west and relying more on thermal power generation due to its geographic conditions, which ultimately leads to a continuous increase in carbon emissions; on the contrary, the power exporting region, due to its favorable geographic location and good natural conditions for clean energy generation On the contrary, power exporting regions, due to their favorable geographical location and good natural conditions for clean energy generation, will not experience a significant increase in carbon dioxide emissions. Analyzing the regional division of ‘West-East Electricity Transmission’, it is obvious that the thermal power generation in the power exporting area of Nantong Road has increased due to the power demand of the load importing area, thus significantly increasing the local carbon dioxide emissions, which further indicates that the regional power generation structure is an important factor affecting the carbon reduction effect of new energy vehicles.

The previous section of the paper has confirmed that under the current energy structure, the promotion and use of new energy vehicles cannot realize their carbon reduction potential. However, as the government continues to focus on carbon neutrality and peak carbon targets, and as the energy mix continues to be optimized and upgraded to become cleaner, the carbon reduction potential of new energy vehicles will be truly unleashed at the beginning of a certain year in the future. The paper calculates this specific year, and obtains the result that the carbon equilibrium point appears in 2033. The emergence of the carbon balance point means that the promotion of new energy vehicles will really start to promote the reduction of carbon dioxide in the transportation industry. At the same time, it shows that with the current level of effort, the efficiency of energy structure change will not enable new energy vehicles to play a role in reducing carbon emissions before the 2030 carbon peak goal is achieved, but it may play a stronger role in promoting the 2060 carbon neutral goal. This puts higher demands on the government's efforts to improve the energy structure, and if the government continues to increase its efforts to optimize the energy structure, it will accelerate the process of new energy vehicles playing a role in carbon emission reduction, and make the promotion of new energy vehicles start to play a real role in carbon emission reduction in advance of 2033 and before 2030.

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