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Spatial-Temporal Evolution of Sales Volume of New Energy Vehicles in China and Analysis of Influencing Factors

Run Sun [1,2], Kun Yang [1,2,*], Zongqi Peng [1,2,*], Meie Pan [1,2], Danni Su [1,2], Mingfeng Zhang [1,2], Lusha Ma [1,2], Jingcong Ma [1,2] and Tao Li [1,2]

[1] Faculty of Geography, Yunnan Normal University, Kunming 650091, China; 2223130018@ynnu.edu.cn (R.S.); pme123@126.com (M.P.); 2223130038@ynnu.edu.cn (D.S.); 2223130015@ynnu.edu.cn (M.Z.); 2333130001@ynnu.edu.cn (L.M.); 2433130001@ynnu.edu.cn (J.M.); litao11@ynnu.edu.cn (T.L.)

[2] GIS Technology Research Center of Resource and Environment in Western China, Ministry of Education, Yunnan Normal University, Kunming 650500, China

* Correspondence: kmdcynu@163.com (K.Y.); pengzongqiynnu@163.com (Z.P.)

Abstract: China's transportation carbon emissions account for 10% of the total, with nearly 90% originating from road transport. Additionally, China is the world's largest automotive demand market. Therefore, in the context of achieving the "dual carbon" goals, the promotion and application of new energy vehicles (NEVs) are particularly crucial. However, the current situation regarding the promotion trends and driving mechanisms of NEVs in China remains unclear. Therefore, this study, based on panel data, explores the spatial-temporal evolution of NEV sales in China from 2016 to 2022 through spatial analysis. Simultaneously, based on correlation analysis and geographical detectors, this study qualitatively and quantitatively investigates the driving factors of NEV sales in China. The results show that: (1) China's NEV sales will increase by 5.7 million units in the seven years from 2016 to 2022, which is an extremely fast growth rate; (2) There are significant spatial-temporal heterogeneities in the sales of NEVs in China. Sales in the eastern region constitute the largest share among the four major economic regions, accounting for 61% by 2022. The northeastern region has the lowest sales, representing only 2.9% of the national total. (3) Among different provinces, the sales in coastal provinces such as Guangdong, ZheJiang, and Jiangsu are much higher than in inland provinces like Tibet and QingHai. (4) The contribution rates of driving factors vary across regions. Overall, however, the order of influence factors is as follows: road length (0.49) > proportion of the tertiary industry (0.48) > road area (0.40). Therefore, infrastructure is identified as the primary influencing factor for the promotion of NEV. This study has revealed the spatial-temporal evolution of NEV sales and their driving mechanisms, aiming to provide theoretical support for the promotion of NEVs in China.

Keywords: new energy vehicles; spatial-temporal evolution; driving factors

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1. Introduction

In the present era, global climate change and ecological environmental issues have become severe challenges that all humanity collectively faces. As one of the significant sources of global greenhouse gas emissions, the transportation industry bears environmental responsibilities that cannot be ignored [1]. Statistics show that in 2019, fossil fuel vehicles contributed to 18% of the global carbon dioxide emissions, highlighting the significant role of the transportation industry in climate change and environmental pollution [2]. The exhaust emissions from these vehicles not only heavily pollute the air but also directly threaten human health, leading to an increasing incidence of diseases such as lung cancer and asthma [3]. With the continued increase in the global vehicle population, it is projected that by 2050, vehicle emissions could potentially double, posing greater pressure and impact on the Earth's climate system and ecological environment [4]. Under the globally concerted

efforts to accomplish the "dual carbon" objectives, addressing the carbon emissions from the transportation industry to alleviate emission reduction pressure has become a primary task. As the world's biggest producer of carbon dioxide emissions, China shoulders major environmental responsibilities [5]. To this end, China has actively participated in global climate governance [6] and is committed to reducing carbon emissions and achieving the "dual carbon" goals [7]. However, due to its large population base, China is also the world's largest automobile market, and its automobile sales and production have always been among the highest in the world. The carbon emissions of new energy vehicles (NEVs) over their entire life cycle are more than 40% lower than those of traditional fuel vehicles [8]. This is of great significance for promoting low-carbon development. Its promotion is a successful method to decrease carbon emissions in the transportation sector and is crucial for China to achieve its "dual carbon" goals [9]. Achieving green and low-carbon development is a common global aspiration, and the development and promotion of NEVs in China has injected new hope into the global green and low-carbon transformation and made China's contribution. As an innovative technical solution, electric vehicles have many advantages, such as zero emissions, low emissions, and high energy efficiency, and are regarded as an important way for the transportation industry to achieve low-carbon transformation [10]. The promotion and application of electric vehicles not only effectively decrease greenhouse gas emissions while enhancing air quality but also provide a feasible solution for sustainable development. Simultaneously, the Chinese government regards the NEV industry as the only way to transition from a prominent automobile nation to a dominant automobile nation [11]. China has clarified the development direction and goals of the NEV industry in the "NEV Industry Development Plan (2021–2035) [12]", which reflects the strategic deployment at the national level. Therefore, the promotion of NEVs in China is not only a necessary action to address the challenges of global climate change as well as a key measure for the reform and advancement of China's automobile industry [13,14] and the realization of environmentally friendly and low-emission growth. Through the promotion of NEVs, China can play a greater role in global climate governance while promoting the sustainable development of the domestic economy.

To address the dual pressures of climate change and vehicle demand, the Chinese government has implemented a series of measures to promote the development of NEVs [15]. These measures include providing purchase subsidies, reducing or exempting purchase taxes, offering free license plates, and extensively building charging infrastructure [16]. This creates a favorable policy environment and infrastructure support for the widespread adoption of NEV. Against the backdrop of addressing global climate change and promoting sustainable development, China is actively embracing the development of NEVs. NEV not only represents the future direction of the automotive industry but also serves as a crucial pathway to achieving the country's "dual carbon" goals and reducing carbon emissions. However, current research is mostly based on performance improvement technologies for NEVs [17,18], including battery technology [19], charging technology [20], etc. Technological improvement is certainly a key link in the development of NEVs, but its promotion is the top priority of NEV development. Only through large-scale promotion can the "dual carbon" goals be achieved and carbon emissions reduced. Research on the sales volume of NEV is relatively scarce; thus, the current promotion status of NEV remains unclear. Therefore, this paper takes "Spatial-Temporal Evolution and Influencing Factors of NEV Sales in China" as its research theme, aiming to conduct an in-depth analysis of the promotion status of NEVs in China and explore the key factors influencing changes in their sales volume.

2. Materials and Methods

2.1. Data Sources and Study Area

The sales data of NEV in China and its 31 provincial-level administrative regions (excluding data from Hong Kong, Macau, and Taiwan) during the period of 2016–2022 used in this paper are sourced from the Data Analysis and Application Service Platform

(daas-auto.com). The population data, regional GDP, residents' consumption levels, and road mileage data are sourced from the National Bureau of Statistics of China's "China Statistical Yearbook" (https://www.stats.gov.cn/, accessed on 10 February 2024). The national and provincial electricity generation data are sourced from the National Bureau of Statistics' "China Electricity Statistical Yearbook" (https://www.stats.gov.cn/), while the employment data are sourced from the National Bureau of Statistics' "China Population and Employment Statistics Yearbook" (https://www.stats.gov.cn/). According to the National Bureau of Statistics, the study area is divided into four major regions: eastern, central, western, and northeastern. The eastern region includes: Beijing (BJ), Tianjin (TJ), Hebei (HE), Shanghai (SH), Jiangsu (JS), Zhejiang (ZJ), Fujian (FJ), Shandong (SD), Guangdong (GD) and Hainan (HI); the central region includes: Shanxi (SN), Anhui (AH), Jiangxi (JX), Henan (HA), Hubei (HB) and Hunan (HN); the western region includes: Inner Mongolia (NM), Guangxi (GX), Chongqing (CQ), Sichuan (SC), Guizhou (GZ), Yunnan (YN), Tibet (XZ), Shaanxi (SX), Gansu (GS), Qinghai (QH), Ningxia (NX) and Xinjiang (XJ); the northeastern region includes: Liaoning (LN), Jilin (JL) and Heilongjiang (HL) (Figure 1).

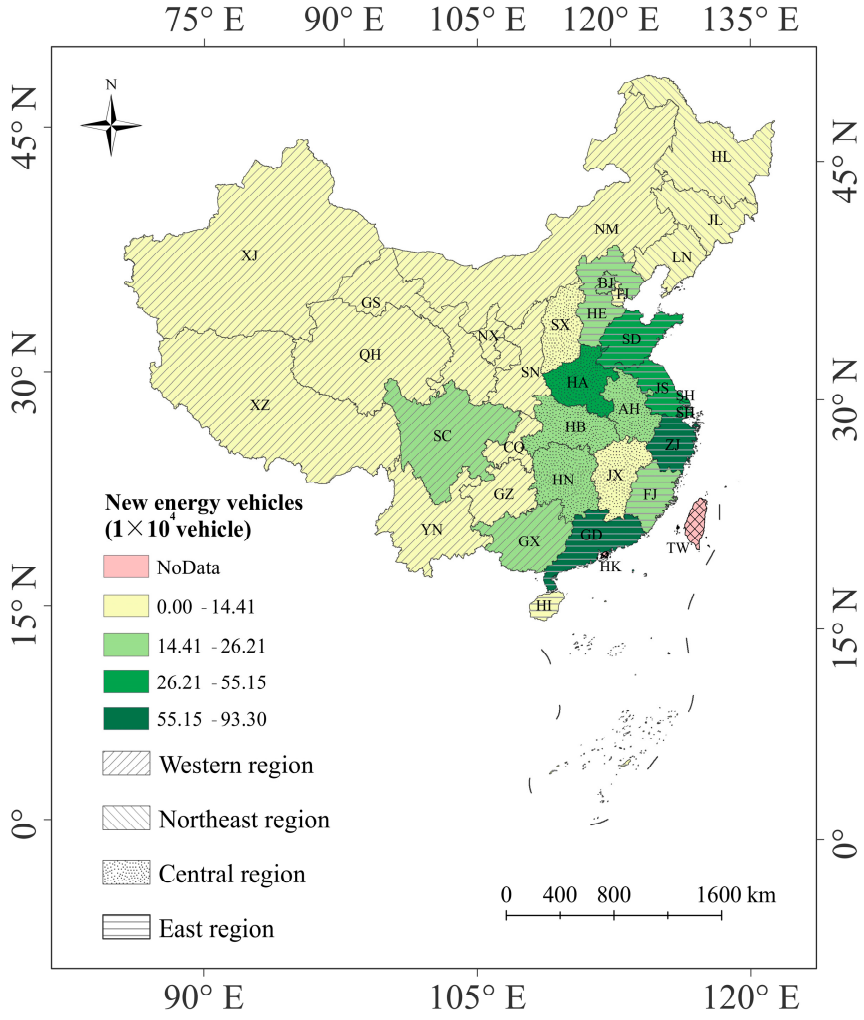


Figure 1. Overview of the study area. This figure includes the new energy vehicle sales data of the four major economic regions and each province in 2022. The four different fills represent the four major economic regions, and the different colors are the graded display of NEV sales in different provinces across the country in 2022, with a unit of 1×10^4 vehicles.

2.2. Research Methods

2.2.1. Spatiotemporal Evolution of New Energy Vehicle Sales

1. Trend Analysis

In order to study the trend of NEV sales over time, we use a linear regression model for analysis. As a common and simple analysis method, linear regression can effectively explore the evolution of NEV sales over time. The equation of the regression line is [21]:

$$y = ax + b \tag{1}$$

where a is the intercept and b is the slope. The coefficient of determination R2 is used to evaluate the goodness of fit of the model [22].

2. Analysis of spatial differences in sales of NEV

(1) Hotspot analysis

In order to study the spatial distribution pattern of NEV sales, we use the hotspot analysis method. Hot spot analysis helps determine which areas have clusters of high or low values, often referred to as "hot spots" or "cold spots" [23]. By calculating z-scores and p-values, we are able to evaluate the statistical significance of clustering of high or low values, thereby accurately identifying real hot spots and cold spots, thereby revealing the spatial clustering characteristics of NEV sales. The specific calculation method of Getis-Ord G^* statistics is as follows [24]:

$$G_i^* = \sum j = 1nW_{ij}X_j - \overline{X}\sum j = 2nX_{ij}S\left[n\sum j = 1nW_{ij}2 - \left(\sum j = 1nW_{ij}\right)2\right]n - 1 \tag{2}$$

In the equation, G_i^* represents the Getis-Ord G^* statistic. When G_i^* is greater than 1.96, the region is a hotspot, indicating a cluster of high sales. When G_i^* is less than −1.96, the region is a cold spot, representing a cluster of low sales. W_{ij} is the spatial weight matrix component, where 1 indicates adjacency and 0 indicates non-adjacency, n represents the number of grids, S is the standard deviation of the sample, and X is the mean sales volume [25].

(2) Spatial autocorrelation

Global autocorrelation analysis can be used to identify whether a phenomenon presents clustering characteristics in space [26]. By adopting this method, we can verify whether the sales of NEVs present a clustering pattern in space. Therefore, we will use the global autocorrelation method to study whether there is a spatial clustering phenomenon in the sales of NEVs. The global spatial autocorrelation analysis is a measure of spatial autocorrelation at the global level, including Moran's I, Geary's C, and other indicators [27]. This paper mainly uses the Moran's I index for analysis, and the formula for calculation is:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}(x_i - \overline{x})^2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{3}$$

where I is the Moran's index; n is the total area of the study area; W is the spatial weight matrix; $(x_i - x)$ represents the difference between the sales volume of new energy vehicles in province i and the average size of all provinces in the neighboring region. The value range of Moran's I is generally between [−1, 1]. When Moran's I is not equal to 0, it indicates that there is a clustering phenomenon. When Moran's I = 0, it means that the variable values are not correlated in space, that is, they are randomly distributed [28].

(3) Local spatial autocorrelation analysis

The Moran's I statistic is a global indicator that can only explain the overall spatial agglomeration characteristics of NEV sales but cannot explain the spatial differences in local areas in detail [29]. When it is necessary to further analyze whether there is a local spatial clustering phenomenon of high or low NEV sales in certain provinces and cities, it

is necessary to introduce the local spatial autocorrelation analysis method [30]. The main indicators include G statistics, Moran scatter plots, the spatial connection local index LISA (Local Moran's I), and other indicators. Among them, the spatial connection local index LISA has the most intuitive spatial visualization effect. Therefore, this paper adopts the LISA local spatial autocorrelation analysis method to measure the importance between the attribute values of each spatial unit and its neighboring spatial units. The calculation formula is [31]:

$$I_i = \frac{(x_i - u)}{m_o} \sum_j w_{ij}(x_i - u) \tag{4}$$

In the formula: $m_o = \sum_i (x_i - u)^2 / n$ is the observed value of a certain attribute feature x in the region; u is the average of all observed values. When the local Moran's I reach the significance level, there are four spatial manifestations: the attribute values of the spatial unit and the surrounding area are both high, represented by High-High; the attribute values of the spatial unit and the surrounding area are both low, represented by Low-Low; the spatial unit attribute value is higher, and the surrounding area's attribute value is lower, and is represented by Low-High; the spatial unit's attribute value is lower, and the surrounding area's attribute value is higher, and is represented by High-Low [32].

2.2.2. Analysis of Driving Factors of New Energy Vehicle Sales

Gross regional product (GRP), household consumption level (HCL), employment status (ES), and infrastructure (IS) are important indicators for measuring the level of socio-economic development, while highway mileage is a basic indicator reflecting the scale of highway construction development [33,34]. This study uses GRP, HCL, HM, and ES as variables reflecting economic development (Table 1). First, the collinearity of the above influencing factors is eliminated by the spass software. At the same time, we found that the above data do not conform to the normal distribution, so we first use Spearman to conduct a correlation analysis between the above influencing factors and the sales of NEVs to qualitatively explore the relationship between the sales of NEVs and the above influencing factors. The calculation formula for Spearman correlation analysis is as follows:

$$p = 1 - \frac{6\sum 2_i^2}{n(n^2 - 1)} \tag{5}$$

where p represents the Spearman rank correlation coefficient, d_i is the rank difference of each pair of observations, that is:

$$d_i = rank(X_i) - rank(Y_i) \tag{6}$$

n is the logarithm of the observation. The value range of the Spearman correlation coefficient is between –1 and 1. After the Spearman analysis, we use the geographic detector to quantitatively explore the degree of influence of different influencing factors on the sales of NEVs. The geographic detector can measure the impact of each independent variable on the variation in the dependent variable, thus pinpointing the factors that exert a noteworthy influence on the dependent variable. The calculation method is as follows:

$$q = 1 - \frac{\sum_{h=1}^{L} Nh\partial^2}{N\partial^2} \tag{7}$$

Here, q represents the degree to which each independent variable explains the spatial variation in the dependent variable. A higher value of q suggests a more significant role of the independent variable in elucidating the spatial variability of the dependent variable. L denotes the stratification of the dependent or independent variable. Nh and σh^2 denote the quantity of units and the variance within each stratum, respectively. N and σ^2 represent the overall number of units and variance across the entire study area, respectively.

Table 1. Selection of influencing factors. This table contains the classification of the selected influencing factors, namely the primary indicators and secondary indicators.

Economic development and population	Gross Domestic Product, GDP Value-added of the secondary industry, VASI Value-added of the tertiary industry, VATI Proportion of urban population at the end of the year, PUPE Population, POP
Residents' consumption level	Per capita consumption expenditure of urban residents, PCEU
Employment	Employees of state-owned units, ESOU Employees in other units, ESIOU Total number of employed persons, TEP Persons employed in urban collective units, PEUC
Infrastructure	The length of the city's roads, LCR The area of the road, ACR Generation, GNR

3. Results

3.1. Temporal and Spatial Variation Characteristics of New Energy Vehicle Sales

3.1.1. Temporal Variation Characteristics of New Energy Vehicle Sales

Overall, from 2016 to 2022, the national sales volume of NEVs has been continuously increasing. By the end of 2022, the sales volume of NEVs nationwide reached 6.1 million units, an increase of approximately 5.7 million units compared to 2016. The average provincial sales volume of NEV in China has shown a slope of 2.7 over time (Table 2), indicating a very rapid growth rate. From the perspective of different regions (Figure 2a). The East region experiences the most rapid increase in sales volume, with the Central region coming next, subsequently followed by the Western region, whereas the Northeast region shows the least growth. Specifically, the growth rates in the West region and the Central region are nearly comparable. From the perspective of average sales volume per province (Figure 2b), the Eastern region continues to have the highest average sales volume. The Central region ranks second, closely aligning with the national average. Following that are the Western region and the Northeast region. In terms of proportions (Table 3), the Eastern region boasts the highest share of NEV sales nationwide, averaging 67% over 7 years, with the highest proportion in 2016 at 72% of national sales. The region with the smallest proportion is the Northeast region, averaging less than 3%. At the provincial level (Figure 3), GD province has the highest sales volume of NEVs, while XZ and QH have the lowest. It is noted that provinces along the coast, such as ZJ and JS, have higher sales volumes compared to inland regions.

Table 2. The table contains the univariate linear regression equations and R^2 of the average new energy vehicle of each region.

Average Sales Volume	Regression Equations	R^2
Country	y = 2.69x – 3.82	0.79
Eastern	y = 5.05x – 6.44	0.80
Central	y = 2.6x – 4.07	0.77
Westward	y = 1.24x – 2.15	0.76
Northeast	y = 0.79x – 1.29	0.75

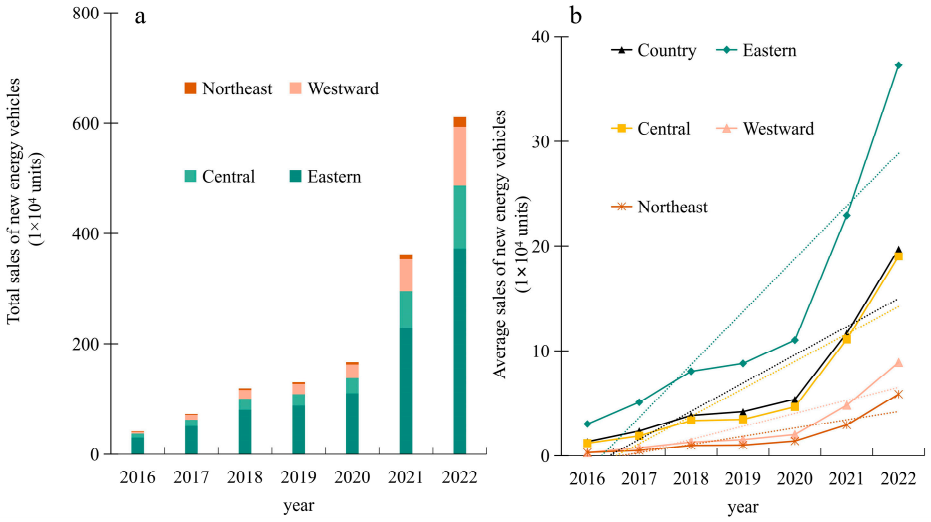


Figure 2. (**a**) is a bar chart showing the percentage of NEV sales in different regions from 2016 to 2022. The four colors represent the four major economic zones. The chart shows the changes in the sales of NEVs in the four major economic zones and their proportion of national sales over time; (**b**) shows the average sales of NEVs in different economic zones. The line charts of different colors represent the changes in the sales of NEVs in different economic zones. At the same time, the trend line represents the changing trend of the sales of NEVs in different economic zones.

Table 3. Sales share of NEVs in the four major economic regions. This table contains the sales share of NEVs in the four major economic regions in the country from 2016 to 2022.

Proportion	Eastern	Central	Westward	Northeast
2016	72.54%	17.22%	8.08%	2.16%
2017	69.80%	15.53%	12.64%	2.03%
2018	67.57%	16.88%	13.07%	2.48%
2019	67.58%	15.96%	14.12%	2.34%
2020	66.16%	16.77%	14.55%	2.53%
2021	63.24%	18.39%	15.94%	2.43%
2022	60.98%	18.67%	17.47%	2.88%
average	66.84%	17.06%	13.69%	2.41%

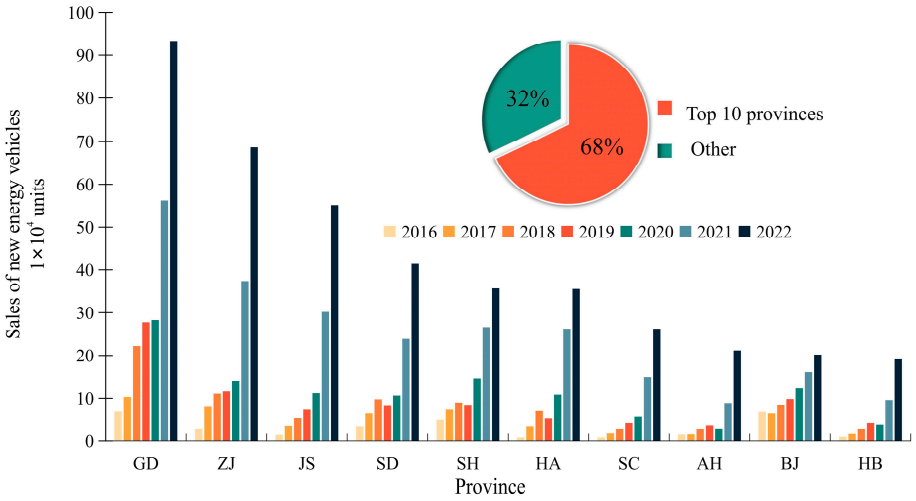


Figure 3. Shows provincial sales of NEVs. The bar chart shows the top ten provinces in terms of sales, and the pie chart shows the proportion of the top ten provinces in terms of sales and other provinces.

3.1.2. Spatial Variation Characteristics of New Energy Vehicle Sales

Through hotspot analysis, we have observed that the hotspot regions for NEV sales are concentrated in the coastal areas of the Eastern region (Figure 4), with AH at the center. Over time, the hotspot area has expanded. As of 2022, the hotspot regions include HB, AH, ZJ, HA, JS, HN, FJ, and JX. These regions indicate spatial clusters of high sales volumes for NEV. In 2016, Sichuan was a cold spot, indicating that sales of NEV were low in and around this province, but the cold spot was not significant. It is worth noting that AH Province has always been a significant hotspot area from 2016 to 2022, indicating that itself and its surroundings are areas with high sales of NEV.

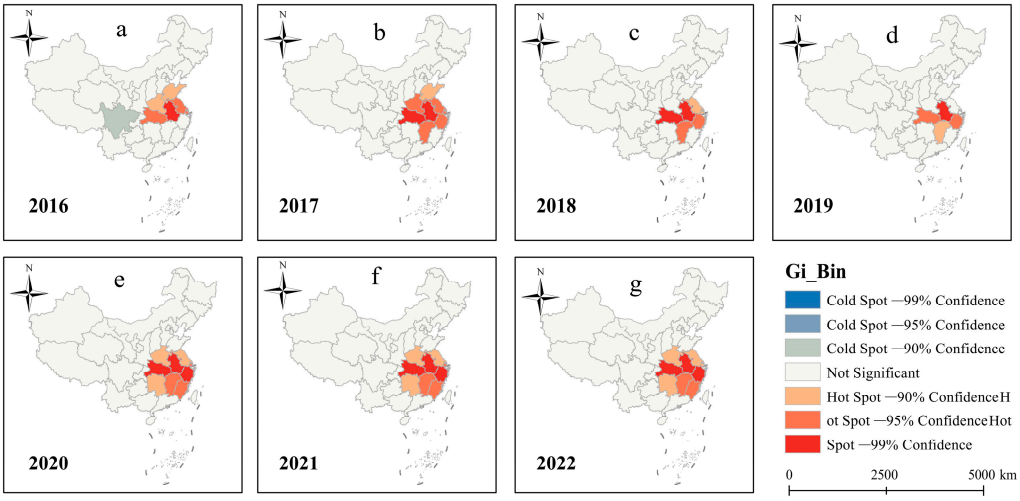


Figure 4. Analysis of hot and cold spots in NEV sales. Figures (**a**–**g**) are sales hot spots in different years from 2016 to 2022.

By analyzing the spatial correlation patterns, we found that the sales of NEV formed four main spatial clustering patterns (Figure 5): low-low clustering, low-high clustering, high-high clustering, and high-low clustering. Low-low clustering is mainly concentrated in the western region; low-high clustering appears in the eastern region; high-high clustering also appears in the eastern region; and high-low clustering is reflected in SC Province. In general, over time, the high-high clustering pattern has increased and the low-low clustering pattern has decreased.

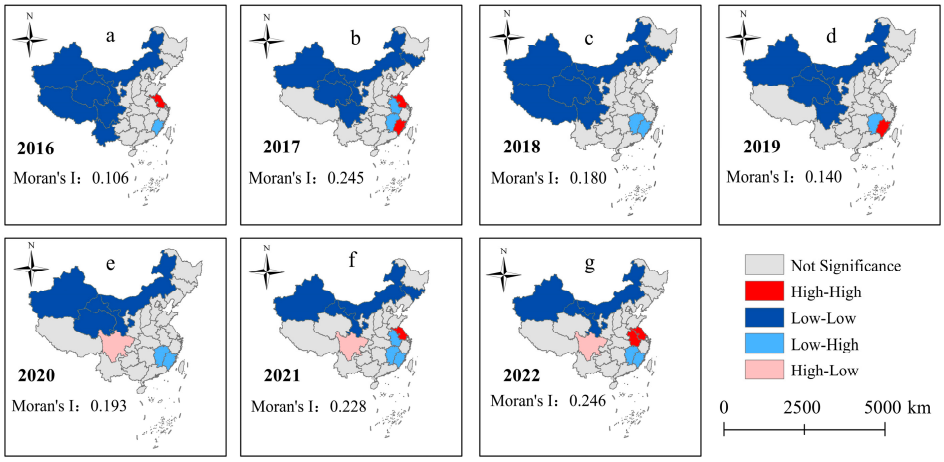
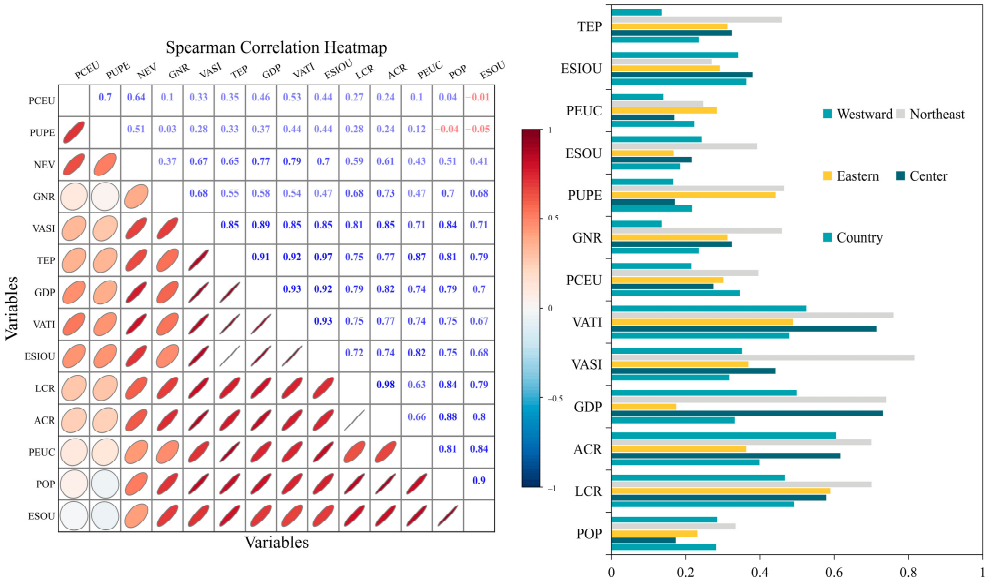


Figure 5. Local spatial autocorrelation distribution of NEV sales. From (**a**–**g**) are the local spatial autocorrelation distribution maps of different years from 2016 to 2022.

3.2. Analysis of Factors Affecting New Energy Vehicle Sales

First, we conducted a correlation analysis between NEV sales and various influencing factors (Figure 6a). VATI had the highest correlation with NEV (0.80), followed by GDP (0.77) > ESIOU (0.71) > VASI (0.68) > TEP (0.65) > PCEU (0.64) > ACR (0.62) > LCR (0.60) > POP (0.52) > PUPE (0.51) > PEUC (0.44) > ESOU (0.42) > GNR (0.38). The above-mentioned driving factors are positively correlated with the sales volume of NEVs, and all of them are above medium correlation, suggesting that these driving factors significantly influence the sales volume of NEVs. To this end, we quantitatively explored the contribution rate of each driving factor to it through the geographic detector (Figure 6b). Through analysis, we found that the contribution rate of each factor impacting different regions is also different. Overall, LCR (0.49) contributes the most to the national NEV sales, followed by VATI (0.48) > ACR (0.40), and the smallest contribution rate is ESON (0.19). In the central region, the largest contribution is GDP (0.73), followed by VATI (0.71) > ACR (0.61). The top three contributions in the eastern region are LCR (0.59) > VATI (0.49) > PUPE (0.44). The three factors with the largest contribution in the western region are ACR (0.61) > VATI (0.53) > GDP (0.50). Finally, the northeastern region is most affected by: VASI (0.82) > VATI (0.76) > GDP (0.74).



(**a**) (**b**)

Figure 6. (**a**) is a correlation analysis diagram between NEV sales and various influencing factors. The red ellipse indicates a positive correlation, and the darker the red, the stronger the positive correlation. The ellipse is approximately circular; the stronger the significance. The blue ellipse indicates a negative correlation. The darker the blue, the greater the negative correlation. Similarly, the ellipse is approximately tilted, indicating a lower significance. The numerical part is the magnitude of the correlation, which is opposite to the color of the ellipse. Red numbers indicate negative correlation, while blue numbers indicate positive correlation. The darker the color, the stronger the correlation. (**b**) The contribution rate calculated for the geodetector. Different colors indicate different comparisons between economic zones and national scales.

4. Discussion

4.1. Temporal and Spatial Distribution Characteristics of New Energy Vehicle Sales

This study has found that the continuous increase in the sales volume of NEV is a phenomenon driven by multiple factors, including infrastructure, employment conditions, and economic development levels, among others. The coverage and convenience of charging station networks are key factors that influence consumers' decisions to buy NEVs [35,36]. The lack of charging infrastructure can indeed hinder the widespread adoption of NEV, while a well-developed charging infrastructure can enhance user experience,

boost sales growth, and promote market expansion [37]. Additionally, road conditions, as part of the infrastructure, play a crucial role in the advancement of NEV. They are not only essential for consumer experience and safety but also directly impact the development and popularization of the NEV market. Increasing employment opportunities can raise residents' income levels, thereby enhancing their ability to purchase NEVs and driving sales growth. The degree of economic advancement directly affects people's purchasing power and consumption levels. Inhabitants in economically advanced areas are more likely to buy NEVs because they have the economic capability to afford the costs associated with these vehicles, thereby stimulating sales growth. Furthermore, factors such as government policy support, shifts in consumer preferences, increasing environmental awareness, and advancements in new technologies also impact the promotion of NEVs. These diverse factors collectively drive the thriving development of the NEV market, leading to a stable growth trend.

The higher sales volume of NEVs in the eastern region of China can be primarily attributed to the region's higher level of economic development, stronger purchasing power among residents, and the significant policy support provided by the government for promoting NEVs, such as vehicle purchase subsidies and free license plates. These policies have greatly stimulated market demand. In addition, the eastern region has made significant investments in the construction of charging infrastructure, boasting a more comprehensive charging network that provides convenience for the use of NEVs. Furthermore, higher economic levels tend to foster stronger environmental awareness, leading individuals to prefer environmentally friendly modes of transportation to reduce their impact on the environment. Moreover, the eastern region possesses a more sophisticated automotive industry base and supply chain, encompassing research and development, production, and sales of NEVs. This provides a favorable industrial environment for the promotion of NEVs. Customers in the eastern region exhibit a higher acceptance of NEV, and the market maturity is relatively advanced, with consumers having a greater awareness and trust in NEV. These factors work together to make the sales of NEVs in the eastern region significantly surpass those of other regions. With the continuous promotion of policies and the continuous optimization of the market environment, this trend is anticipated to persist. For the promotion of NEV in the northeast and western regions, full consideration should be given to climate conditions and geographical environments. In the northeastern region, the cold winter climate poses challenges to the battery performance and range of NEVs. In low temperatures, the chemical processes in the battery decelerate, resulting in a reduction in the vehicle's range. Therefore, there is a need to develop and promote battery technologies that can withstand low-temperature environments. In the western region [38,39], extremely high temperatures and dry climate conditions may be encountered, which pose requirements for the cooling systems and materials of the batteries [40]. In terms of geographical environments, the northeastern region features complex terrain with mountainous areas and roads covered in snow and ice [41], which pose requirements for vehicle maneuverability and traction. The western region, characterized by vast land and a sparse population, may require considerations regarding the construction and distribution of charging infrastructure, as well as the costs associated with maintenance and operation. Additionally, the western region possesses 78% of the national wind energy technical development capacity and 88.4% of the photovoltaic technical development capacity, establishing a robust energy basis for the advancement of NEVs. The provinces of GD, AH, and ZJ represent hotspots in terms of NEV sales, with GD and ZJ standing out as provinces with higher sales volumes, while AH emerges as a notably significant hotspot region. Through data analysis until June 2023, it was found that the ratio of electric vehicles to charging stations in China is 2.4:1, and when considering only public charging stations, this ratio drops to 7.5:1. Among the three provinces of ZJ, AH, and GD, the public charging station ratios in AH and GD are 3.9:1 and 3.2:1, respectively, surpass those in the national average. However, ZJ's public charging station ratio stands at 8.3:1, currently lagging behind the national average. As a result, the sales volume of NEV in ZJ is slightly lower compared to

AH and GD. Compared to the provinces of ZJ, AH, and GD, XZ and QH have relatively fewer charging infrastructure facilities, especially in remote areas. The lack of charging stations restricts the usage and popularization of NEVs in these regions.

4.2. Driving Factors of New Energy Vehicle Sales

Road length and area directly reflect the level of road infrastructure construction in a country or region. Good road infrastructure is a prerequisite for the use and popularization of NEVs. The longer the road and the larger the area, the wider the area that can be driven, which provides more driving routes and usage scenarios for NEVs. Simultaneously, road length can reflect the economic development level in a region. In areas with low economic development, insufficient road construction and maintenance may have a potential impact on the sales of NEVs. Due to infrastructure limitations, consumers in these areas may lack purchasing power or have low demand for NEVs. For VATI, its growth is frequently linked with the progress of the economy and the rise in per capita income. With the improvement of economic level, consumers' purchasing power has increased, which makes more families able to buy NEVs; then, the growth of VATI is usually accompanied by the acceleration of urbanization. Urbanization results in the clustering of populations within cities, consequently escalating the need for urban transportation. As one of the solutions for urban transportation, the sales of NEVs have also increased accordingly; simultaneously, many fields in the tertiary industry, such as education [42] and information technology, have a high awareness of environmental conservation and sustainable growth. With the improvement of public environmental awareness, the demand for clean energy and low-carbon lifestyles has increased, which has promoted the sales of NEVs [43]. While promoting the development of the tertiary industry, the government often also introduces a series of environmental protection policies and regulations, such as restricting the use of traditional fuel vehicles and providing subsidies for NEVs. The introduction of these policies directly promoted the sales of new energy vehicles. Finally, with the progress of the tertiary industry, the construction of urban infrastructure has accelerated, including charging stations and charging piles required for new energy vehicles, which has further promoted the sales of new energy vehicles. The sales of NEVs in the eastern region are impacted by the percentage of the urban population. This is mainly due to the rapid economic development in this region, where the increase in urban population also adds to traffic pressure. NEVs, as clean energy vehicles, can effectively reduce urban pollution and meet the transportation needs of cities. Moreover, the eastern region boasts a higher level of economic development and relatively higher residents' income levels, thereby affording greater purchasing power for acquiring NEVs. Subsequently, spatial hotspot analysis reveals that the eastern region represents the fastest-growing market for NEV sales in China. The hotspot regions have been consistently situated in the eastern region since 2016. Based on our findings, we have observed that governments in the eastern region typically implement NEV promotion policies earlier, including incentives such as purchase subsidies, free license plates, and exemptions or reductions in vehicle purchase taxes. These policies have significantly stimulated market demand. Compared to the eastern region, GDP serves as a significant factor driving sales in the western region. In contrast to the higher income levels in the eastern region, residents in the western region have relatively lower income levels. Therefore, to a certain extent, GDP promotes sales growth in the western region and also constrains sales within the region. Hence, GDP stands out as a crucial driving force in this context. Secondly, the road area and length in the western region also contribute significantly to the sales of NEVs. The western region is vast, and roads are an important symbol of its development. With the implementation of national strategies such as Western Development, the economic development and infrastructure construction in the western region, including the improvement of transportation networks, have been promoted, thus promoting the sales of NEVs in the region. The situation in the central region is akin to that in the western region. What is different from the western region is that the advancement of the tertiary industry is an important driving force for the

sales of NEVs. First, the implementation of national strategies such as the rise of the central region has promoted the economic development and industrial upgrading of the central region and the vigorous development of its tertiary industry. For the tertiary industry, especially the service industry, the promotion of NEV can reduce its costs and maximize its benefits. In the Northeast region, whose economic structure is dominated by the secondary industry, the growth of the tertiary industry and GDP reflect the overall economic situation and industrial upgrading in the region. These factors have a combined impact on the sales of NEVs because consumers in these regions may give greater consideration to the industrial performance and economic practicality of the vehicle. In summary, we found that infrastructure is indeed the primary factor affecting the promotion of NEVs. Only with the support of sufficient and sound infrastructure can NEVs be better integrated into daily travel, give play to their environmental protection and energy-saving advantages, and achieve the goal of low-carbon travel [44].

The spatial heterogeneity of NEV sales and the different emphases on the driving factors of NEV sales in different regions can, to a certain extent, reflect the differences in development levels among various regions in my country. The eastern region includes provinces such as BJ, TJ, HE, SH, JS, ZJ, FJ, SD, GD, and HI. These regions have a high level of economic development, a strong manufacturing base, and advanced service industries. The region is close to the coastline and is a center of foreign trade. Its continuous development has led to an accelerating urbanization rate, thereby attracting a large number of rural populations to migrate and forming a rapid development cycle. Although the development of the western region lags behind that of the eastern region, it is also constantly accelerating its development with the development of national strategies. The most significant feature is the continuous improvement of infrastructure construction, such as the continuous expansion and improvement of the road network. However, simultaneously, the western region's regional ecological environment is fragile, so the promotion of NEV in the western region is particularly important. The development level of the central region is between that of the east and the west. As China's "granary," the central region has a solid agricultural foundation, while the industry and service industries are also developing rapidly. Therefore, with the development of the tertiary industry, the sales of NEVs are also increasing. The northeastern region was once China's heavy industrial base and has a strong industrial foundation. Although its development level is relatively backward, it has faced the challenges of economic transformation in recent years, and its economic growth rate is relatively slow, which has led to GDP becoming both a driving force and a "resistance" for its new energy sales. However, economic revitalization can be achieved through policy support and industrial structure adjustment. Simultaneously, the imbalance in regional development has once again led to spatial heterogeneity in the promotion of NEV. To solve this problem, we must gradually overcome the imbalance in regional development and improve the promotion of NEVs across the country by improving infrastructure, strengthening policy support and guidance, and strengthening publicity and education, as well as cooperation and innovation.

4.3. Shortcomings and Prospects

This paper explores the current promotion trend of NEVs in my country through the analysis of NEV sales and driving factors. However, this paper still has the following shortcomings: First, the analysis of NEV sales only focuses on the national, regional, and provincial scales without further refinement; second, the selection of driving factors does not consider the influence of natural factors on NEV sales. XZ, QH, and other provinces have extreme climate conditions and harsh geographical environments, which will limit the promotion of NEVs to a certain extent. Third, this article does not consider the impact of policies on the sales of NEVs, but policy factors should be one of the important reasons affecting their sales [45]. Fourth, when using geographic detectors to explore the driving mechanism of NEV sales, this paper only explored the impact of a single factor on NEV sales but did not further explore the influence of the interplay among various influencing

factors on NEV sales. However, this paper explored the influencing mechanism of NEV sales through driving analysis, providing a theoretical basis for the next step of promotion.

5. Conclusions

The promotion of NEVs is the key to my country's transportation emission reduction. Therefore, this article explores the spatial and temporal evolution of NEV sales and their driving factors, aiming to provide a theoretical basis for their promotion. The research results show that: (1) On a national scale, my country's NEV sales have grown rapidly from 2016 to 2022, with an increase of 5.7 million units in 7 years. The average sales volume of NEVs in each province in the country has changed over time with a slope of 2.7. From a regional scale, the fastest-growing sales volume is in the eastern region, followed by the central region and the western region. The northeastern region has the slowest growth rate. Among them, the growth rate of the western region and the central region is not much different. Among the four major economic regions, the sales volume in the eastern region is the largest, accounting for 61% as of 2022, and the region with the lowest sales is the Northeast, accounting for 2.9% of national sales. From a provincial scale, sales of NEVs are highest in GD and lowest in XZ and QH. (2) Spatially, my country's NEV sales have significant spatiotemporal heterogeneity. The hot spots for NEV sales are concentrated in the eastern coastal areas, with AH Province as the center. Over time, hotspot areas continue to expand. As of 2022, hotspot areas include HB, AH, ZJ, HA, JS, HN, FJ, and JX. (3) Through spatial correlation pattern analysis, we found that NEV sales have formed four main spatial clustering patterns. Low-low clustering is mainly concentrated in the western region; low-high clustering appears in the eastern region, and high-high clustering also occurs in the eastern region, and high-low clustering is reflected in SC. Simultaneously, the high-high clustering pattern has strengthened, and the low-low clustering pattern has weakened over time. (4) There are differences in the contribution rates of driving factors in different regions. Overall, the largest contribution to the national NEV sales is LCR (0.49), followed by VATI (0.48) > ACR (0.40), and the smallest contribution rate is ESON (0.19). In the central region, the largest contribution rate is GDP (0.73), followed by VATI (0.71) > ACR (0.61). The top three contributing factors in the eastern region are LCR (0.59) > VATI (0.49) > PUPE (0.44). The three factors with the largest contribution rates in the western region are ACR (0.61) > VATI (0.53) > GDP (0.50). Finally, the Northeast region has the largest contribution rate: VASI (0.82) > VATI (0.76) > GDP (0.74). However, from an overall perspective, infrastructure is the primary factor restricting the promotion of NEVs. (5) Judging from the spatial heterogeneity of sales volume and driving mechanism, it is evident that China's regional development is still in an uneven stage. Due to uneven regional development, there is obvious spatial heterogeneity in the promotion of NEVs. To address this issue, first it is essential to adopt differentiated policies, strengthen infrastructure construction, promote the balanced promotion and development of NEVs nationwide, and make important contributions to achieving global sustainable development goals. This article provides theoretical support for the promotion of NEVs.

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