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Study on Regional Imbalance in Residents' Green Product Consumption

-- Taking New Energy Vehicles as an Example

Yi Li*

School of Applied Economics (School of Digital Economics), Jiangxi University of Finance and Economics, Nanchang, China

*zqiuxingkong@163.com

Abstract

Scientific construction of the index system for measuring the fairness of new energy vehicle subsidies and in-depth analysis of the spatial characteristics of new energy vehicle subsidy policies. Based on the new energy vehicle subsidy data of Chinese cities from 2014 to 2019, this study quantitatively analyzes the imbalance of the average subsidy and total subsidy of pure electric passenger cars among cities under the background of subsidy policy retreat. Through visual map display, calculation of Gini coefficient and Suits coefficient, and drawing of Lorenz curve, this paper delves into the differences in the distribution of pure electric passenger car subsidies among different cities. The study reveals the imbalance between the distribution of new energy transportation subsidies and sales volume, and analyzes the potential mechanisms that lead to the imbalance of total subsidies in different cities. The results show that the average subsidy level in coastal cities is generally higher than that in inland; the total subsidy imbalance between regions is mainly driven by the factor effect caused by income disparity and the structural effect caused by heterogeneity in consumption tendency; in addition, the average subsidy shows obvious spatial characteristics of "high high agglomeration" and " low low agglomeration". low-low agglomeration" characteristics. We aim to enrich and improve the construction and measurement of new energy vehicle subsidy fairness index system in Chinese cities, so as to provide theoretical support for the formulation of relevant policies.

Keywords

Pure Electric Passenger Cars; New Energy Vehicle Subsidies; Sales Imbalance; Regional Differences.

1. Introduction

Globally, the development of high-tech industries is receiving more and more attention, in which financial subsidies and tax breaks have become the norm as an effective policy tool for the government to promote the development of the industry [1]. In the critical period of China's economic transformation, the government's role in guiding the industry is particularly significant. New industries, especially the new energy automobile industry, as an important source of innovation drive under the new economic normal, are not only related to the country's energy security and sustainable development, but also a key area that responds to the society's demand for green environmental protection [2].

Between 2016 and 2017, the new energy vehicle subsidy policy underwent a significant adjustment, with a direct drop of 40%.On March 26, 2019, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the

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National Development and Reform Commission jointly issued the Notice on Further Improving the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles, which specifies a further regression of the subsidy for new energy commercial vehicles, with an average of 50% compared to the 2018 basis. and plans to gradually complete the regression by the end of 2020. These policy adjustments have had a profound impact on the independent innovation and healthy development of the new energy vehicle industry.

However, in the context of subsidy regression, the existing literature has not yet rigorously analyzed subsidy allocation in Chinese cities using equity indicators and spatial autocorrelation indicators. This study aims to fill this gap, and through the comprehensive use of fairness assessment and spatial autocorrelation analysis, to explore the regional imbalance of subsidies in depth, to provide policy makers with decision-making references, and to provide theoretical support and practical guidance for the sustainable development of new industries.

2. Literature Review

The rapid development of the new energy vehicle market has attracted extensive academic attention, especially in the area of market-technology interaction. A study by Yongqing Xiong and Xi Wang emphasized the role of market demand diversity in driving technological innovation, noting that the pursuit of high performance and reliability by the government and commercial sectors, as well as private consumers' concern for environmental protection and energy efficiency, have combined to drive technological advances in range and charging convenience [3]. These findings provide an important perspective for understanding how market demand shapes technological innovation.

Further, domestic scholars have conducted in-depth analyses of the factors influencing consumers' willingness to buy. Chen-Yu Wang summarized the key factors and made targeted suggestions [4]. Niu Liwei, on the other hand, focused on consumer purchase intention and discussed the effectiveness of policy guidance [5]. Li Wenting analyzed the characteristics of different consumer groups' purchasing behaviors from the perspective of consumer heterogeneity [6], and these studies provided multi-dimensional insights to reveal consumer behaviors.

At the policy level, the issue of new energy vehicle subsidies has become a hot research topic. Zhou Yahong et al. explored the impact of government subsidy policy on industrial innovation and healthy development by constructing an enterprise behavioral response model [2]. The empirical analysis by Wang Wei et al. then focused on the role of government subsidies on enterprise performance [7]. These studies provide a theoretical basis for assessing policy effects and guiding policy formulation.

Fairness is also an aspect that cannot be ignored in policy research. Yu Zuo and Li Xiang pointed out that the current new energy vehicle subsidy policy may violate the Antimonopoly Law [8]. Wei Feng et al. studied the impact of government subsidies on supply chain decisions under fairness concerns [9]. Sun Renjing, on the other hand, evaluated the effect of subsidy regression policy and provided theoretical support for the adjustment and termination of subsidy policy [10].

Although existing studies have explored the regional heterogeneity of new energy vehicle consumption and production from multiple perspectives, the analysis of the regional imbalance of subsidies is still insufficient. This paper aims to fill this gap by analyzing the regional distribution of subsidies in detail, exploring their relationship with market space, and providing new perspectives and suggestions for the optimization of new energy vehicle policies.

ISSN: 2692-7608 DOI: 10.6981/FEM.202409_5(9).0011

3. Data

3.1. Data Preprocessing

The data for this study mainly comes from the official website of each city government and authoritative websites such as Beida Faber Law Database. Based on government documents, we screened, cleaned and integrated the data according to classification criteria such as city, year and range, and constructed a complete dataset of new energy passenger car subsidies in Chinese cities from 2014 to 2019, which provides a solid data foundation for subsequent analysis. The research object focuses on private passenger cars, excluding large buses, public vehicles and small cabs.

During the implementation of the data collection and conversion process, we often encountered different data specifications in different cities, which made data organization complicated and cumbersome. For example, different cities may have their own unique range guidelines, and plug-in electric vehicles are covered differently in different provinces. Zhejiang Province, for example, has included micro EVs in its subsidies for 2017-2019, while micro EVs are not included in the national subsidy and are not included in the subsidy policies of other Chinese provinces. In addition, some cities allocate municipal subsidies based on provincial subsidies, while others use national subsidies as a guideline. These factors increase the complexity of data processing. This situation has a negative impact on the subsequent empirical research. Therefore, accurate data processing not only helps to reduce the error, but also lays the foundation for the writing of subsequent papers.

In the process of data processing, we follow the national subsidized mileage as a benchmark, and unify the differentiated mileage in each region to the national subsidy standard, so as to make the calculation of the average subsidy amount more accurate. In addition, for redundant car types, we likewise use the nationally subsidized car types as a reference to clean the data to reduce errors. For different stages of the same year, we consistently use the calculated average as the standard. For the problem of varying standards of data ratios, we calibrated the data through multiple verifications and the application of multiple methods to ensure the authenticity of the data.

By visualizing and analyzing the average subsidies and consumption of new energy vehicles in Chinese cities from 2014-2019, and combining the per capita GDP data of each city in the city statistical yearbook, we calculated the Gini coefficient and the suits coefficient, and then carried out horizontal fairness and vertical fairness studies. In addition, using the spatial correlation analysis method, we further explored the correlation between the spatial distribution characteristics of the new energy vehicle subsidies and the sales volume and so on.

The data analysis and visualization results of this study not only provide a comprehensive description of the new energy vehicle subsidy policy in Chinese cities, but also provide a new perspective for understanding the regional differences in subsidy policy, fairness and its spatial effects.

3.2. Data Analysis

Based on the national subsidy policy for new energy vehicles, as shown in Table 1, this study first divides vehicles into different categories based on their range. On this basis, the average policy subsidy refers to the aggregation of three policy funds, namely national subsidy, provincial subsidy and municipal subsidy, within each category, and the calculation of its average value, in order to reflect the strength of the comprehensive policy support received by vehicles under each range category.

According to the data in Table 1, between 2014 and 2017, pure electric passenger vehicles with a range of 250 km or more were regarded as high range new energy vehicles and enjoyed the highest state subsidy in the pure electric vehicle segment. Entering 2018, the policy has refined

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the subsidy standard for high range models, dividing the original single standard of R≥250 km into three more specific intervals: 250≤R < 300 km, 300≤R < 400 km, and R≥400 km. This adjustment reflects the policy's differentiated support for models with different range capabilities. By 2019, the policy is further optimized to provide the highest amount of state subsidy only for pure electric passenger cars with R≥400 km, while pure electric vehicles with a range of less than 250 km are completely out of the scope of state subsidy. These changes reflect the gradual adjustment and precise positioning of the new energy vehicle subsidy policy in line with technological progress and market demand.

Table 1. State subsidies for new energy passenger cars, 2014-2019

year	Subsidized vehicles	Range R (working condition method, kilometers)	Amount of State subsidy (million yuan)
2014	Pure electric passenger cars	80≤R<150	3.325
		150≤R<250	4.75
		R≥250	5.7
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	3.325
2015	Pure electric passenger cars	80≤R<150	3.15
		150≤R<250	4.5
		R≥250	5.4
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	3.15
2016	Pure electric passenger cars	100≤R<150	2.5
		150≤R<250	4.5
		R≥250	5.5
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	3
2017	Pure electric passenger cars	100≤R<150	2
		150≤R<250	3.6
		R≥250	4.4
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	2.4
2018	Pure electric passenger cars	150≤R<200	1.5
		200≤R<250	2.4
		250≤R<300	3.4
		300≤R<400	4.5
		R≥400	5
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	2.2
2019	Pure electric passenger cars	250≤R<400	1.8
		R≥400	2.5
	Plug-in Hybrid Passenger Vehicles (including Programmable)	R≥50	1

According to Figure 1, the highest value of the average policy subsidy for new energy vehicles in China's cities declined year by year between 2014 and 2017; however, this trend reversed and showed an upward trend between 2017 and 2018. This was followed by another fall in subsidies between 2018 and 2019. The reason behind this change is that, against the

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background of gradual subsidy regression, the policy subsidies for pure electric passenger cars with range in different intervals (250≤R < 300, 300≤R < 400, R≥400) were adjusted in 2018, compared to the single subsidy for range R ≥ 250 in 2017, and in order to promote the continuous progress and innovation of new energy vehicle technology, the In 2018, the range R≥250 was refined to 250≤R<300, 300≤R<400, R≥400, and in particular, the subsidies for vehicles with a range of 300≤R<400 and R≥400 kilometers were increased, which led to slight fluctuations in the overall subsidy level.

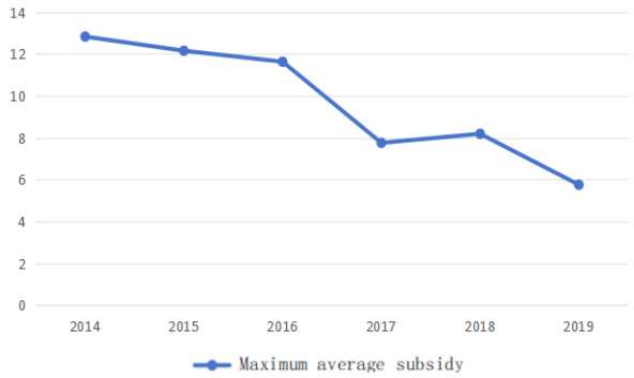


Fig. 1 Maximum average subsidy for new energy vehicle policies in cities across the country, 2014-2019

4. Research Methodology

This study draws on the research methodology of Shuocheng Guo and Eleftheria Kontou, and adopts the Gini coefficient and Suits coefficient proposed by them to measure the horizontal and vertical fairness of new energy vehicle subsidy policies in Chinese cities. In addition, in order to quantify the spatial distribution characteristics of the subsidy policy, this study introduces the calculation of the global Moran index to measure the spatial correlation of the total subsidy or the average subsidy among different cities.

4.1. Equity Analysis

4.1.1. Gini Coefficient

This study uses the Gini coefficient as a measure of horizontal equity. Horizontal equity is concerned with whether all cities have equal access to funds from the subsidy policy, regardless of their income levels. The formula for calculating the Gini coefficient is shown below:

$$\text{Gini}=\frac{K-l_x}{K}=1-\frac{L_x}{K} \tag{1}$$

As stated in the study by Shuocheng Guo and Eleftheria Kontou, in equity analysis in transportation, the Lorenz curve is a common tool for describing the cumulative distribution of incomes of different groups. The curve is equally applicable to represent any quantity allocated to a population, such as a subsidy. Let K be the area of the triangle in Figure 1, where K = 1/2 × 100% × 100% = 0.5. The black dashed diagonal line represents the ideal perfectly fair distribution of subsidies. The area Lx under the Lorenz curve can be calculated exactly by integrating from 0 to 1, but in this study we use the following approximate formula:

$$L_x \approx \sum_{i=1}^{n} \frac{1}{2}[R(x_i)+R(x_{i-1})](x_i\text{-}x_{i-1}) \tag{2}$$

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where xi represents the cumulative percentage of the reference indicator (e.g., GDP per capita or sales volume) within city i, and R(xi) represents the cumulative percentage of the total amount of subsidy within city i. We use city as an individual unit, so n equals the total number of cities participating in the subsidy policy, and in the case of the Gini coefficient, n equals the total number of people who purchased pure electric passenger cars through the subsidy policy. The value of the Gini coefficient lies between 0 and 1: when the coefficient is 0, it indicates perfect equality, and when the coefficient is 1, it indicates perfect inequality.

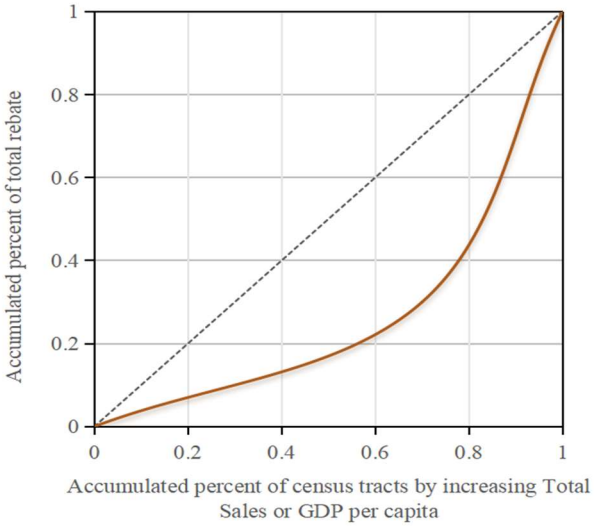


Fig. 2 Schematic shape of the Lorenz curve

4.1.2. Suits Coefficient

This study follows the research framework of Shuocheng Guo and Eleftheria Kontou and focuses on assessing the fairness of the subsidy policy for pure electric passenger cars across different income groups. In particular, we focus on whether the subsidy distribution is equalized across cities with different economic levels.

The calculation of the Suits coefficient, although based on the formula of the Gini coefficient, differs in the application of the Lorenz curve. In this study, the X-axis of the Lorenz curve is ranked according to the increase in GDP per capita, while the Y-axis represents the cumulative share of the total subsidy for pure electric passenger cars. Through the application of the Suits coefficient, this study aims to reveal differences in the distribution of subsidy policies across income groups and to assess their vertical equity. This approach provides a more comprehensive perspective to identify and quantify the inequality in the distribution of subsidies across the board.

4.2. Spatial Analysis

Spatial models help identify which cities are suitable targets for subsidies. Spatial weighting matrices generally include a spatial adjacency matrix, a spatial distance matrix, a spatial nesting matrix, and an economic distance matrix. We use the spatial adjacency matrix to calculate the global Moran index.

We first compute a weight matrix that describes the adjacency between two spatial units of analysis. The adjacency of cities is represented by a binary variable with post-adjacency weights. This means that for non-adjacent spatial units i and j that do not share a boundary, the elements of the spatial weight matrix are 0, otherwise wij= 1.

Global Moran's Index (Moran's I) is used to assess the global spatial autocorrelation of spatial data. The original assumption is that the variable values between spatial cells are randomly distributed, i.e., there is no spatial correlation. The statistic measures the correlation between

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the variable values and their spatially lagged values, where the spatially lagged values can be expressed as deviations from the spatial cell means. The global Moran's index is calculated as equation (3):

$$I = \frac{\sum_i \sum_j w_{ij} z_i z_j / s_0}{\sum_i z_i^2 / n} \tag{3}$$

For observations in city i, zi= xi- $\bar{x}$, where $\bar{x}$ is the mean value of the subsidy variable x, and queen contiguity is measured by the element wij from the spatial weight matrix. the variable S0 is computed by the formula $\sum_i \sum_j w_{ij}$, which is the sum of all the weights on i and j, and n denotes the number of observations. the significance of Moran's I is assessed on the basis of z-values and p-values.

By calculating the global Moran's index, we can assess whether there is significant spatial aggregation or dispersion in the spatial distribution of subsidy amounts across cities. This analysis helps us to better understand the spatial effects of subsidy policies and provides insights to policy makers on how to optimize the distribution of subsidies.

5. Empirical Analysis

In this study, the map visualization method is first used to characterize the spatial distribution of subsidies for pure electric passenger cars among new energy vehicles. Subsequently, the inequality of subsidy distribution is further quantified by calculating the Gini coefficient and Suits coefficient and plotting the Lorenz curve, and finally, the spatial correlation of the average subsidy, total subsidy, and total sales volume of pure electric passenger cars is described by the Moran index. This analysis helps to reveal the differences in new energy vehicle subsidies in different regions and identify regional imbalances in the distribution of new energy transportation funds.

5.1. Descriptive Analysis

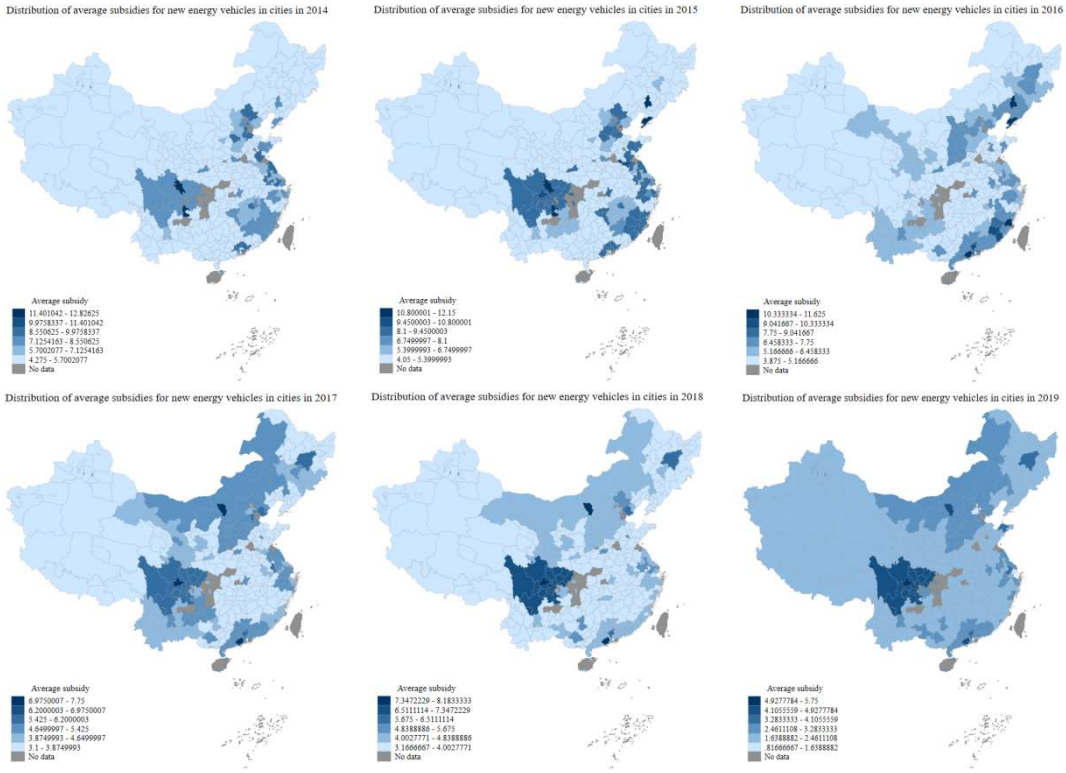
5.1.1. The Average Policy Subsidy in Cities Declines Year by Year, the Subsidy in Sichuan Province is Higher than that in the Whole Country, and the Subsidy in Coastal Cities is Higher than that Inland

Under the environment of gradual regression of the new energy vehicle subsidy policy, the average policy subsidy of Chinese cities shows an overall decreasing trend. This is despite the fact that between 2017 and 2018, policy adjustments were made to promote the development of new energy vehicles with high range, especially for models with a range R≥250 km, and the subsidy amount was increased, which led to a brief rise in the level of the average policy subsidy during that time period. In addition to this, the average policy subsidy imbalance of new energy vehicles in Chinese cities generally shows a slowing down trend from the time series of 2014 to 2019.

Through spatial distribution analysis, the average policy subsidy in Sichuan province is significantly higher than that in neighboring cities among the cities within the province, especially in the three core cities of Luzhou, Mianyang, and Chengdu, where the average policy subsidy in 2014 was as high as 128,262,250 yuan, 128,250,000 yuan, and 85,500,000 yuan, respectively. In contrast, the average policy subsidies in other cities in Sichuan province did not reach the level of these three major cities. However, from a macro perspective, the average policy subsidies of all cities in Sichuan Province are generally higher than those of other provinces, a phenomenon that is mainly attributed to the higher provincial subsidy policy in Sichuan Province.

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Over time, the differences in policy subsidies among different cities are gradually narrowing. For example, the color difference in the subsidy distribution map in 2019 has been significantly reduced compared to 2014, reflecting the narrowing of the subsidy gap. In addition, coastal cities still maintain a higher average level of policy subsidies compared to inland cities, which may be related to the level of economic development and policy preferences in coastal areas.



This map is based on the standard map with review number GS(2020)4619, and the base map is unmodified.

Fig. 3 Average policy subsidies for new energy vehicles in cities across China, 2014-2019

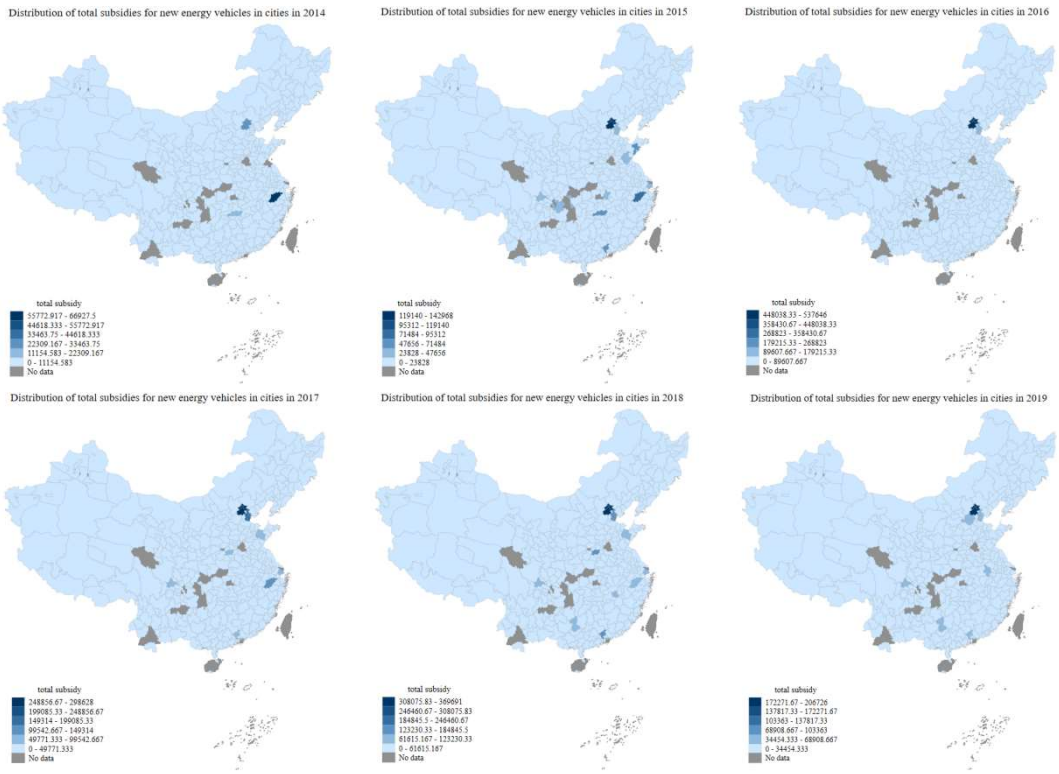
5.1.2. Concentrated Distribution and Disparity of Total Subsidies for New Energy Vehicles, with more Total Subsidies in Cities with High Sales Volume

The analysis results in Figure 4 show that the total policy subsidy for new energy vehicles shows concentration in geographical distribution, mainly concentrated in a few cities, and these areas do not show obvious spatial aggregation effects. Over time, the total subsidies in some cities have increased, which is mainly attributed to the growth in sales. In 2018, for example, Beijing, Tianjin and Zhengzhou City ranked among the top three cities in terms of total subsidies, with 36,969,130,000 yuan, 17,083,540,000 yuan and 14,723,620,000 yuan, respectively. At the same time, these three cities also ranked in the top three in terms of sales of pure electric passenger cars, with 57,307, 38,068 and 30,053 units, respectively. This suggests that sales volume is an important factor in the total subsidy amount for a city.

In the analysis of city new energy vehicle subsidies from 2014 to 2019, we note that there are obvious differences in the strength of new energy vehicle subsidies in various cities during this period. Specifically, highly subsidized cities are mainly distributed in some developed cities and provincial capitals. In 2014, for example, there was a huge difference in the subsidy range among cities, with Shanghai having the highest total subsidy of RMB 661.82 million, while the lowest subsidy was only RMB 42.75 million.

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By analyzing the graphs comparing the annual average subsidy to the total subsidy, we observe a clear trend: those cities that received higher total subsidies had similarly higher average subsidies. This phenomenon may be attributed to the fact that the higher subsidy amount promotes the growth of local new energy vehicle sales, which in turn pushes up the total subsidy amount. This phenomenon may have led to increased subsidy imbalances between different regions, widening the subsidy differences between regions. In 2018, for example, the average subsidy amounts in Beijing, Tianjin, and Zhengzhou were 50,400 yuan, 53,760 yuan, and 53,760 yuan, respectively, and the subsidy levels in these cities were in the top 11% percentile of all cities, highlighting the impact of the subsidy policy and its potential boost to sales in these regions.



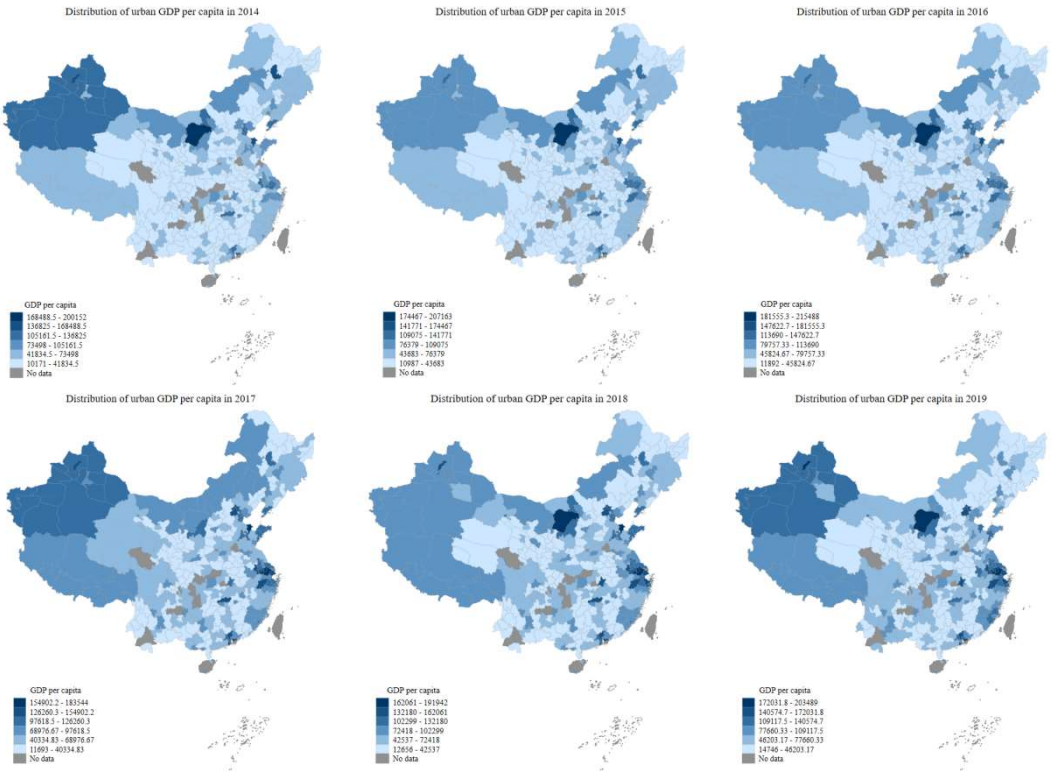
This map is based on the standard map with review number GS(2020)4619, and the base map is unmodified.

Fig. 4 Total subsidies for new energy vehicle policies in cities across China, 2014-2019.

5.1.3. Uneven Distribution of Subsidies, Sales Scale and Sales Structure Affect Total Subsidies

There are significant differences in the distribution of actual subsidy amounts within a given region. Although the average subsidy amount is not high in some regions, the overall subsidy amount is still high due to the large scale of sales of new energy vehicles and the sales structure favoring high-range mileage models. New energy vehicles with high mileage range have a clear advantage in sales due to enjoying higher average policy subsidies. For example, in Weifang, Shandong Province, in 2018, its average policy subsidy was RMB 33,600, which was one of the lowest levels in that year, but due to its sales of 25,585 pure electric vehicles and the sales of high-range mileage models with a range of R ≥ 250km accounting for as much as 93.87% of its sales, it resulted in its total subsidy amount reaching RMB 884,669,000, which was ranked fourth. In addition, high range models are priced higher due to higher costs, and their market acceptance is closely related to the purchasing power of local residents. Weifang's GDP per capita is in the top 34%, indicating that residents have strong purchasing power, which may be one of the reasons for its high total subsidy.

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This map is based on the standard map with review number GS(2020)4619, and the base map is unmodified.

Fig. 5 Distribution of gross regional product per capita in cities across the country, 2014-2019

5.2. Horizontal Equity Analysis

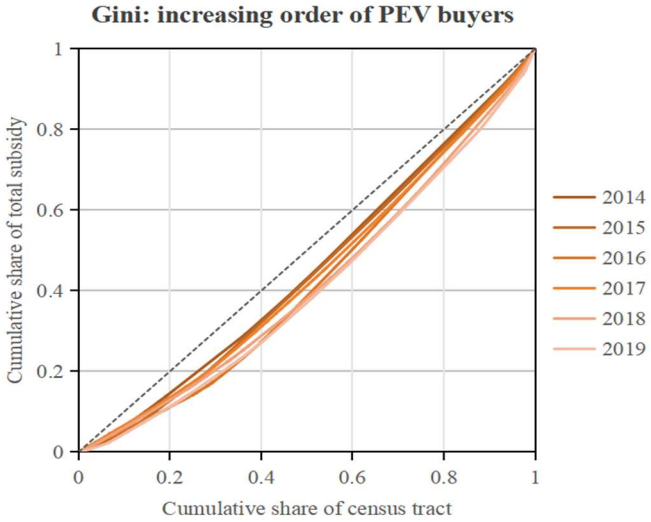


Fig. 6 Lorenz curve by year: Gini coefficient:total sales and total subsidy

The results of the analysis of the Lorenz curve show that in the Chinese new energy vehicle market during the period from 2014 to 2019, although the subsidies received by vehicles accounting for 60% of sales did not reach 60% of the total subsidies, they accounted for no less than 47% of the subsidies. The trend of the Lorenz curve over this period shows that the curve maintains a small distance from the diagonal line representing the ideal state of fair distribution. The proximity of the curve to the diagonal line reflects the relative fairness of new energy vehicle subsidies among different cities, showing that the subsidy mechanism is more balanced on the whole.

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Overall, the trend of total subsidy and sales volume is consistent. Although the actual subsidy curve slightly deviates from the ideal diagonal, the deviation is not large, indicating that the total subsidy increases with the growth of sales, reflecting the positive correlation between the subsidy policy and market demand.

5.3. Vertical Equity Analysis

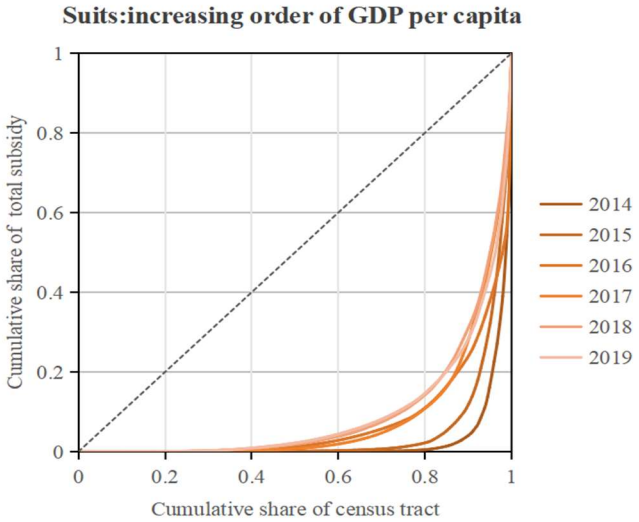


Fig. 7 Lorenz curve by year: Suits coefficients:GDP per capita and total subsidy

As the Lorenz curve in the figure shows, the total subsidy gap tends to narrow over time. in 2014, the municipalities with GDP per capita located in the lowest 96% received only 23% of the subsidy funds, while the municipalities with the highest 4% of GDP per capita received more than 75% of the total subsidy. By 2019, cities with GDP per capita located in the lowest 96% receive 46% of the total subsidy dollars. Over time, the Lorenz curve gradually moves closer to the diagonal, suggesting that the distribution of subsidies among different purchasers is equalizing. However, despite the reduction in the subsidy gap, the Lorenz curve is still far from the diagonal, indicating that inequities in the distribution of subsidies among different income groups are still significant.

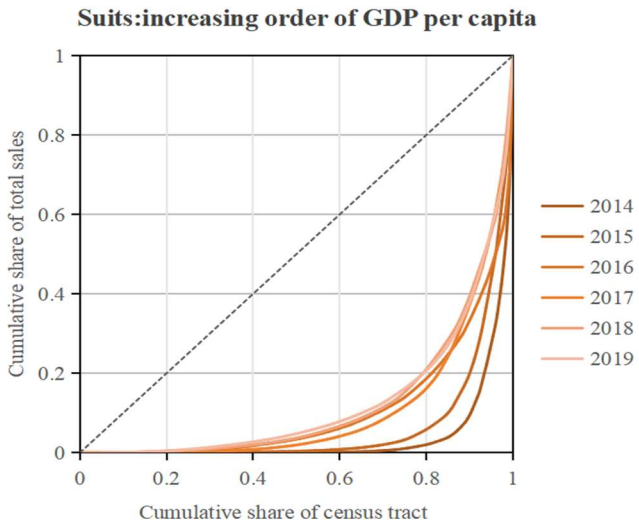


Fig. 8 Lorenz curve by year: Suits coefficient: GDP per capita and total sales

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As shown in the Lorenz curve in the figure, the uneven distribution of new energy vehicle sales among different income groups shows a decreasing trend from year to year. in 2014, the cities with GDP per capita located in the lowest 90% of the cities had less than 10% of the total sales of new energy vehicles, while the cities with the highest 5% of GDP per capita accounted for more than 70% of the total sales. By 2019, the share of sales in the lowest 90% of cities increases to 38%. This change suggests that the distribution of sales among buyers of different incomes has equalized over time. Nonetheless, there is still a large gap between the Lorenz curve and the diagonal line of perfect equality, reflecting the fact that inequity in new energy vehicle purchases remains evident across cities with different income levels.

By comparing and analyzing Figures VI and VII, we can find that the Suits coefficients calculated on the basis of per capita gross regional product and total subsidies, as well as the Lorenz curves obtained from the Suits coefficients calculated on the basis of per capita gross regional product and total sales volume, both show similar trends over the period from 2014 to 2019. The findings reveal that differences in total subsidies between cities are mainly influenced by differences in sales volumes. Specifically, the sales volume of new energy vehicles is higher in cities with higher income levels, and accordingly, these cities receive more total subsidies; relatively, cities with lower income levels receive less subsidies due to lower sales volumes. This suggests that the uneven distribution of sales volume is the dominant factor contributing to the uneven total subsidy.

However, within the same year, the Lorenz curve obtained from the Suits coefficients based on GDP per capita and total subsidy shows a greater degree of deviation from the diagonal line compared to the Suits coefficients based on GDP per capita and total sales volume. This phenomenon implies that there may be other factors besides sales volume that contribute to the unbalanced distribution of total subsidy, which may include, but are not limited to, the structure of the local economy, policy orientation, and market maturity, etc., and are worthy of further investigation.

5.4. Spatial Correlation Analysis

Verify whether there is spatial correlation among the average subsidy, sales volume, and total subsidy of new energy vehicles. The methods to test the spatial autocorrelation mainly include Moran's index method (Moran's I), Geary's index method (Geary's C), and Cetis-Ord index method, etc., among which the Moran's index method is the most widely used, so this paper adopts the Moran's index method (Moran 's I) to calculate the spatial effects of subsidies and sales in each year under the spatial adjacency matrix, as shown in Table 2.

Table 2. Global Moran index of new energy vehicle sales and subsidies in Chinese cities, 2014-2019

Year	Irebate	total sales	total subsidy
2014	0.034	0.02	0.014
2015	0.046*	-0.02	-0.011
2016	0.044*	-0.01	-0.01
2017	0.086**	0.055**	0.053**
2018	0.064**	0.033	0.03
2019	0.029	0.027	0.019

Based on the data from 2014 to 2019, the global Moran's indices of the logarithm of the average subsidy (Irebate), the total sales (total sales), and the total subsidy (total subsidy) in China's new energy vehicle sector were computed by using the spatial adjacency matrix to explore the spatial autocorrelation of these variables.

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The results of the analysis show that the Moran's I index for Irebate passed the significance test between 2015 and 2018, with the indexes for 2015 and 2016 being significantly positive at the 10% level of significance, while the indexes for 2017 and 2018 were significantly positive at the 5% level of significance. This positive autocorrelation in consecutive years indicates that the logarithmic value of the average subsidy exhibits spatial clustering, i.e., regions with higher subsidies tend to be geographically adjacent to regions with similarly higher subsidies, reflecting the "high" clustering and "low" clustering characteristics of the average subsidy. agglomeration characteristics.

Compared with Irebate, the Moran's I index for total sales and total subsidy only reached the 5% significance level in 2017, showing a significant positive autocorrelation, a finding that reveals the geospatial clustering of total sales and total subsidy in that year.

For total sales, the positive autocorrelation in 2017 suggests that regions with higher sales tend to be spatially adjacent to other regions with higher sales. This phenomenon may reflect a trend of regional concentration in market development or a clustering effect of demand for new energy vehicles within a given region. This may be related to factors such as local policies, infrastructure development, consumer preferences or market access conditions. Similarly, in 2017, the Moran's I index for total subsidies is significantly positive with a significance level of 5%, suggesting that regions with higher total subsidies also exhibit positive spatial autocorrelation.

However, this significant positive autocorrelation is not observed in other years, suggesting that the spatial distribution of total sales and total subsidies may be influenced by a variety of factors that vary over time. For example, the data for 2014 and 2019 show that the Irebate index does not pass the significance test despite being positive, which could mean that the spatial effect of the subsidy policy was not significant or was offset by other factors in those years.

6. Conclusion and Recommendations

Based on the relevant subsidy and sales data of new energy vehicles in Chinese urban agglomerations from 2014-2019, this paper systematically analyzes the imbalance in the distribution of pure electric vehicle subsidies at the city level by using the Gini coefficient and spatial correlation methods, and evaluates the distribution of the subsidy measures among different income groups and their spatial correlation. The study finds:

From the perspective of average subsidy, the spatial distribution of policy subsidies for new energy vehicles in China shows obvious imbalance, and the regions with higher average subsidies for new energy vehicles are mainly located in developed provinces, large cities, and coastal and riverine cities. Although the policy adjustments between 2017 and 2018 had briefly boosted the subsidies for high-range models, the average subsidies as a whole still showed a downward trend from 2014 to 2019.

From the total subsidy perspective, the total subsidy is concentrated in a few developed cities and provincial capitals, showing significant differences in subsidy amounts across regions. There is a positive correlation between total subsidy amount and sales volume, indicating that regions with high sales volume tend to receive more subsidies, which may be related to the promotion of local policies. Those cities that receive higher total subsidies may have similarly higher average subsidies. This phenomenon may be attributed to the fact that higher subsidies promote the growth of local sales of new energy vehicles, which in turn pushes up the total subsidy amount. This phenomenon may lead to increased subsidy imbalances across regions. In addition, in some regions, despite the low average subsidy amount, the overall subsidy amount is still high due to the large scale of new energy vehicle sales and the sales structure that favors high range models.

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The Lorenz curve shows that although the distribution of total subsidies among purchasers with different incomes tends to be balanced, the large distance between the Lorenz curve and the diagonal line still indicates that there is inequality in the distribution of subsidies among different income groups. Differences in total subsidies between cities are mainly affected by differences in sales volume, but the Suits coefficient analysis implies that, in addition to sales volume, there may be other factors affecting the unbalanced distribution of subsidies, and these findings deserve further exploration and consideration.

The logarithmic value of the average subsidy over the period from 2015 to 2018 exhibits significant spatial positive autocorrelation through the global Moran index analysis, while the spatial aggregation of total sales volume and total subsidy is particularly prominent in 2017. This indicates that in that year, regions with higher sales volume tend to be spatially adjacent to other regions with higher sales volume, and regions with higher total subsidies tend to be spatially adjacent to other regions with higher subsidies.

Based on these findings, the following policy recommendations are made:

If equity is an important objective when planning the allocation of subsidy funds, then clusters characterized by low incomes and limited subsidies can be specific targets for subsidy funds. Specifically the following:

First, refine the subsidy policy. The new energy vehicle subsidy policy is refined and adjusted to take into account the differences in the level of regional economic development and market maturity. Through differentiated subsidy standards, the subsidy gap between developed and less developed regions is reduced, and the balanced distribution of resources among different regions is promoted. At the same time, the effectiveness of the subsidy policy should be regularly evaluated to ensure that the subsidy funds can be efficiently used to promote the popularization of new energy vehicles and technological innovation.

Second, strengthen the synergy between local and central policies. Encourage local governments to formulate specific implementation rules in accordance with the central policy guidance, combined with the local actual situation. For example, Zhejiang Province has incorporated miniature pure electric vehicles into the scope of subsidies in light of the specific situation. Local governments should focus on the consistency of subsidy policy and local development planning, through the provision of supporting infrastructure, optimize the use of new energy vehicles and other measures to improve the overall effectiveness of subsidy policy.

Third, promote the combination of market-driven and policy support: while continuing to implement the necessary financial subsidies, the market mechanism should be gradually guided to play a greater role in the promotion of new energy vehicles. Encourage enterprises to reduce costs through technological innovation, improve product quality and competitiveness, and reduce dependence on policy subsidies. In addition, consumer education and market information services should be strengthened to increase consumer awareness and acceptance of new energy vehicles and to promote market self-regulation and sustainable development.

With these conclusions and recommendations, the study aims to provide decision support to policy makers, promote the healthy development of the new energy vehicle industry, and realize the rational allocation of resources.

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