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The Positive Reinforcement of New Energy Vehicles on the Overall Automobile Market

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Abstract: New energy vehicles (NEVs), including battery electric vehicles (BEVs), plug-in hybrid vehicles (PHEVs) and fuel cell electric vehicles (FCEVs), have gained significant traction in recent years both in China and globally due to heightened environmental awareness, government support, and technological innovations. While some studies suggest that the rise of NEVs has led to a decline in traditional fuel vehicle (TFVs) sales, particularly in developed countries with high EV adoption rates, others argue that the NEV market's growth has spurred innovation throughout the entire automobile industry, which would have a positive impact on the entire automobile market. This paper delves into the intricate relationship between NEVs and the traditional automobile market, concentrating on whether the surge in NEVs causes crowding-out effects or fosters positive reinforcement. Our data analysis supports the latter notion, revealing that NEVs have not supplanted TFVs but have, in fact, energized the entire automotive sector. Drawing insights from existing literature, this paper analyses the key drivers behind this positive reinforcement, emphasizing the role of government policies, consumer behaviour, and industry innovations in shaping this dynamic.

Keywords: new energy vehicles, traditional fuel vehicles, positive reinforcement

1. Introduction

1.1. Research background

China witnesses the automobile industry undergoing a transformative shift and industrial upgrading with the rapid growth of New Energy Vehicles (NEVs), which encompass Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Fuel Cell Electric Vehicles (FCEVs). This transition is driven by various factors, including heightened environmental awareness, government policies, and technological advancements [1]. NEV sales in China have climbed 838 times between 2011 and 2022, as indicated in Table 1 and Figure 1. Figure 2 and Figure 3 illustrate that, while the monthly production and sales of TFVs are growing slowly (periodic fluctuations excluded), the monthly production and sales of NEVs are increasing rapidly. Consequently, the market share of NEVs is expanding quickly in both production and sales. The China Association of Automobile Manufacturers' most recent statistics show that by 2022, China will have led the world in both new energy vehicle production and sales for eight straight years. There were 7.058 million new energy vehicle manufacturing units and 6.887 million new energy vehicle sales units in China alone in 2022,

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for a market penetration rate of 25.6%. This achievement was higher than the 2025 interim goal outlined in the "New Energy Vehicle Industry Development Plan (2021-2035)" [1]. In addition to production, research, and development of NEVs is also expanding rapidly. The number of companies relevant or devoted to NEVs has grown at an annualised pace of 248% over the last five years. What is more, China recorded 62,661 new NEV-related firms as of December 2020, an increase of 74% from the previous year [2]. Zeng et al. estimated that China's NEV sales will climb steadily over the ensuing decades, reaching 3.03 million units in 2030, even in the worst of the six scenarios with the Chinese government's supporting policies for the NEV industry weakening and the subsidies ceasing [3].

Table 1: Sales of NEV in China, 2011-2022 (unit: ten thousand).

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sales	0.82	1.28	1.8	7.5	33.1	50.7	77.7	125.6	120.6

Sources: China Association of Automobile Manufacturers

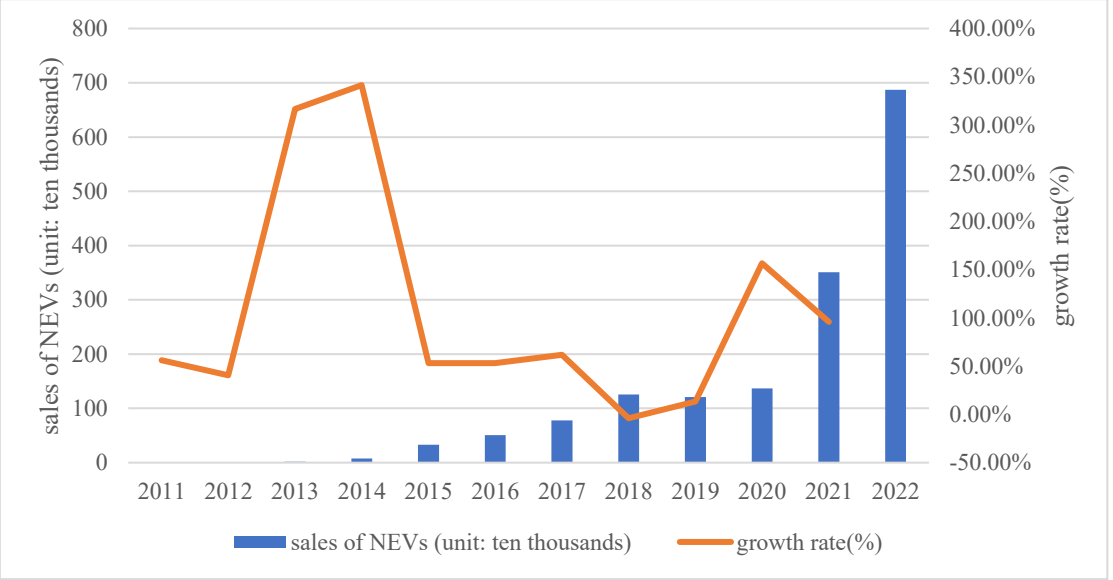

Figure1: China's NEV sales and growth rate, 2011-2022.

[1] General Office of the State Council of the People's Republic of China. (2020). New Energy Vehicle Industry Development Plan (2021-2035).

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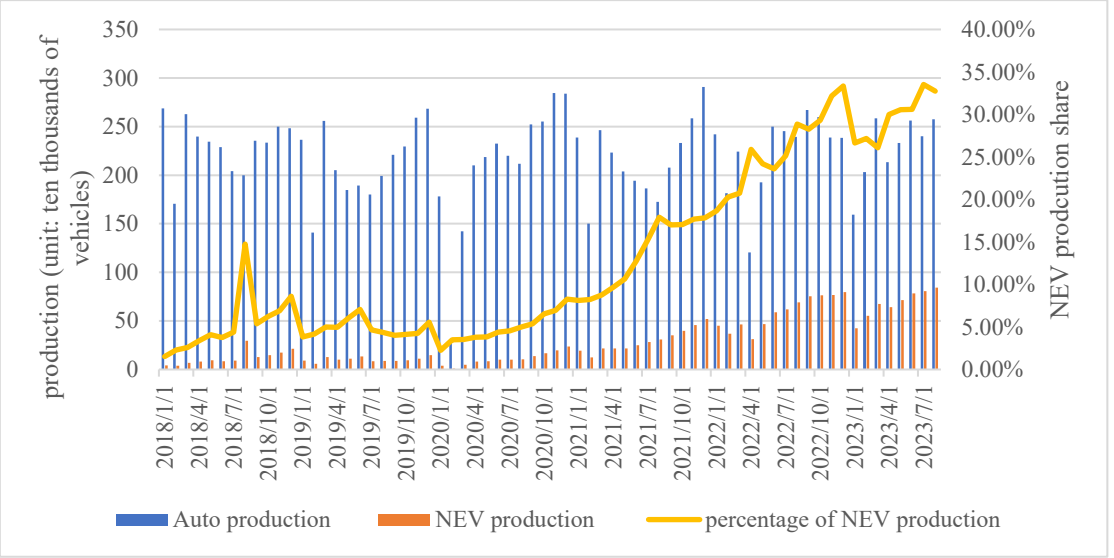

Figure 2: Monthly Automobile Production, NEV Production, and NEV Production Share in China, 2018 - 2023.

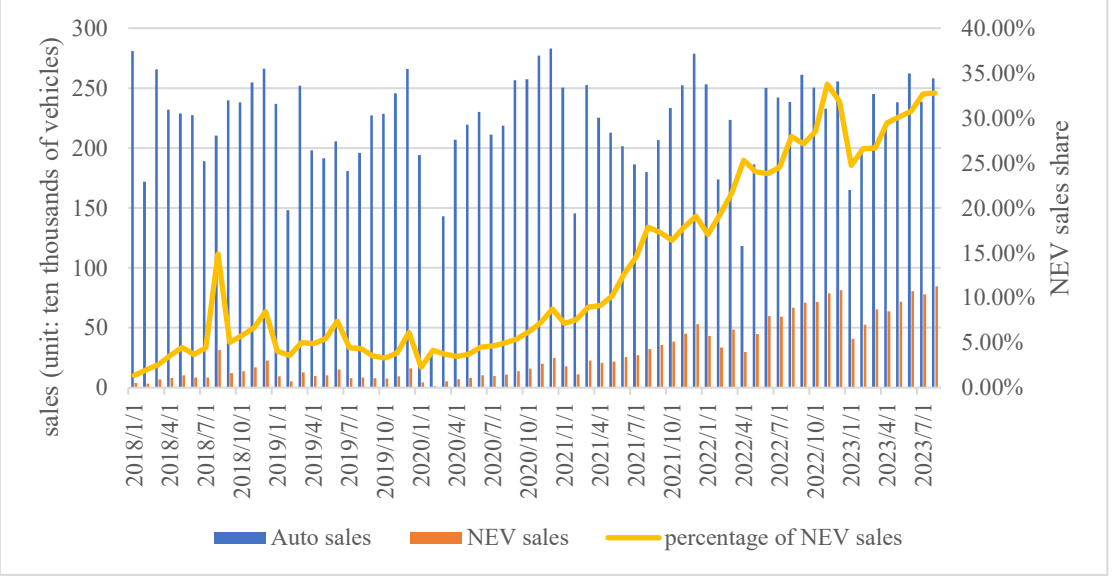

Figure 3: Monthly Automobile Sales, NEV Sales, and NEV Sales Share in China, 2018 - 2023.

1.2. Research objectives and significance

It is believed that the rapid rise of NEV is useful for alleviating energy shortages, assuring national energy security, and enhancing environmental quality. Currently, there is a global consensus and a trend of coordinated action surrounding the development of NEV [4]. By developing the NEV industry, China may reduce its unsustainable reliance on oil imports and its deteriorating environmental pollution, which is essential for attaining its carbon peaking and carbon neutrality goals [5]. As NEVs gain prominence and the market share of NEVs rises significantly, questions arise regarding their impact on the traditional fuel vehicles (TFVs) market and the entire automobile market. A proper assessment of this impact allows for more precise predictions of the automobile industry's future landscape. It also contributes to China's green development by providing empirical support for automobile industry strategies. Currently, research in this sector focus mostly on analysing the

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underlying causes of the impact, both positive and negative ones [6] [7]. Some studies involve modelling and data analysis; however, most research directions focus on delivering suggestions for government subsidy policies and pricing strategies for new energy cars using modelling [8] [9]. There is relatively little research that investigates the influence of new energy cars on the automobile market from the perspective of data analysis and empirical research. This paper utilizes monthly production and sales data for both NEVs and the entire automobile market, sourced from China's Ministry of Industry and Information Technology. The purpose of this study is to delve into the intricate relationship between NEVs and traditional fuel vehicles. The goal is to ascertain whether the growing prominence of NEVs leads to crowding-out effects or fosters positive reinforcement on the automobile industry.

1.3. Structure of paper

This paper commences by providing a concise definition and classification of New Energy Vehicles (NEVs). It subsequently conducts a comprehensive review of the existing literature on the impact of NEVs on the automobile market. Following this, the paper employs an OLS regression model to process and analyse the data, and ultimately get the conclusion that NEVs have a positive reinforcement effect on the automobile market. At the end, the paper acknowledges its limitations and highlights potential research directions.

2. Literature review

2.1. Definitions and classifications of NEVs

The terminology used to define and classify New Energy Vehicles (NEVs) indeed varies from one country to another, reflecting differences in policy focus and technological emphasis. For instance, in Japan, NEVs are often referred to as "low-pollution vehicles," encompassing a range of technologies. In the United States, NEVs are commonly known as "alternative fuel vehicles." China has a more specific definition for NEVs, as outlined in the "Energy-Saving and New Energy Vehicle Industry Development Plan (2012-2020)," published by the State Council of China on September 7, 2012. In China, NEVs refer to vehicles primarily or completely driven by new energy sources. This includes categories such as battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell vehicles (FCVs) [2].

To gain a deeper understanding of NEVs, it is essential to categorize them based on their power sources and characteristics. Battery Electric Vehicles (BEVs) are vehicles that only use batteries to store energy. They use electrical energy from the batteries to power electric motors, propelling the vehicle. The advantages of pure EVs include zero emissions, minimal noise, simplicity in structure, and high energy conversion efficiency. However, challenges such as limited battery energy density and high battery replacement costs need to be addressed [10]. Plug-In Hybrid Vehicles (PHEVs) are a hybrid electric vehicle subtype that combines electric drive principles with traditional internal combustion engines. Despite having the word "hybrid" in their name, plug-in hybrid electric vehicles (PHEVs) are very different from conventional hybrid vehicles, which mix petrol and electric powertrain. PHEVs, on the other hand, use the same drivetrains and driving modes as BEVs. These vehicles have a relatively large battery capacity that can be externally charged, enabling short-distance all-electric driving. When the battery charge is depleted, PHEVs switch to hybrid mode, primarily relying on the internal combustion engine while simultaneously charging the battery. In the long run, PHEVs offer customers with a transitional model between BEVs and traditional fuel

[2] General Office of the State Council of the People's Republic of China. (2012). Energy-Saving and New Energy Vehicle Industry Development Plan (2012-2020).

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vehicles (TFVs) [10]. In a fuel cell, an electrochemical reaction between hydrogen and oxygen generates electricity, which serves as the major power source for Fuel Cell Vehicles (FCVs). FCVs have plenty of advantages. Firstly, the only byproduct of the electric-chemical reaction of the fuel cell is water, making FCVs a kind of genuine clean energy vehicle. Also, the energy conversion efficiency of FCVs typically ranges from 60% to 80%. In comparison, Traditional Fuel Vehicles (TFVs) powered by internal combustion engines have significantly lower energy conversion efficiency, typically falling in the range of 30% to 40% [11]. Due to its characteristics, hydrogen fuel cell vehicles have been considered the future ideal solution for new energy vehicles. However, the hydrogen fuel cell vehicle technology bottleneck is still significant, the main one being the unsolved car hydrogen storage technological problem. Along with these factors, the development of hydrogen fuel cell vehicles is further constrained by the limited lifespan and high cost of fuel cells as well as the expensive infrastructure and sluggish growth of hydrogenation stations [6] [11]. Unlike BEVs, which are already available in the market, the consensus among experts is that it will require a minimum of a decade of development before fuel cell technology for automobiles is ready for widespread adoption [11].

2.2. Research on the relationship between NEVs and TFVs

Regarding the impact of New Energy Vehicles (NEVs) on the automobile market, current literature presents three main attitudes. Some studies suggest that NEVs are unlikely to significantly affect the traditional automobile industry in the next thirty years, indicating few correlations. In contrast, they emphasize the influence of policy uncertainties on the traditional automobile market [6]. Other research contends that NEVs have a crowding-out effect on the traditional automobile market. These studies primarily focus on two aspects. Firstly, they explore the substitutability and replacement pathways of traditional fuel vehicles by NEVs. They establish price substitution models based on the total lifecycle cost comparison of vehicles and offer recommendations concerning government NEV policies, including subsidies, charging infrastructure and fuel prices, and corporate pricing strategies on NEVs [7]. The factors influencing consumers' propensity to buy NEVs are the subject of another direction of research. Questionnaire surveys are frequently used as data sources, and techniques like panel mixed Logit models and principal component analysis are employed for statistical studies [8] [9]. There are reasons for believing that New Energy Vehicles (NEVs) have a crowding-out effect on Traditional Fuel Vehicles (TFVs). Firstly, from an economic perspective, NEVs are considered substitutes for TFVs. Consumers who opt for NEVs may choose them over TFVs due to factors like environmental concerns, cost savings on fuel, and government incentives. This substitution effect can reduce the market share of TFVs. Secondly, the concept of disruptive innovation, as put forth by Clayton Christensen, posits that novel technologies and products have the potential to disrupt established markets by providing easier, more cost-effective, or more convenient alternatives [12]. If recognised as an independent system from TFVs, NEVs, with their potential environmental benefits and evolving technology, can be seen as a disruptive force in the automobile industry, challenging the dominance of TFVs.

The third perspective suggests that NEVs exert a positive reinforcement effect on the traditional automobile market. This perspective highlights the potential synergy and complementary relationship between NEVs and traditional fuel vehicles. Several factors contribute to this positive reinforcement effect. A key driving factor for this positive reinforcement is the transition towards modular production, the widespread adoption of platform-sharing strategies, and the optimization of the automobile industry's structure. From a modular perspective, the traditional automobile industry is currently undergoing a process of disassembly and reassembly, allowing valuable modules to be decomposed and integrated [13]. Many automobile manufacturers have introduced modular and platform-based approaches that enable NEVs and TFVs models to share production lines, components,

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and system modules. For instance, Magna has successfully developed modular solutions such as electronic steering systems, air conditioning systems, and electronic hydraulic power steering systems, which can be utilized across NEVs and TFVs alike. This method has resulted in reduced development costs and lead times for both NEVs and TFVs [14]. In addition to promoting the optimization of the traditional automobile industry, this trend towards transformation has also increased industry capacity, fostering the development and innovation of new energy vehicles [13]. Consumer behaviour plays a crucial role in the positive reinforcement of the automobile market. While NEVs have made significant strides, they still have limitations, especially in terms of range and charging infrastructure. As a result, many consumers perceive NEVs as suitable for short commutes and urban driving, often considering them as secondary vehicles within their households. This consumer behaviour drives the overall expansion of the automobile market because NEVs cater to specific use cases, while TFVs continue to meet other needs, such as long-distance travel. The coexistence of NEVs and TFVs provides consumers with more choices, introduces new consumer groups, and creates sales opportunities, contributing to the overall growth of the automobile industry [15]. Furthermore, when consumers contemplate purchasing NEVs, they typically prioritize factors such as battery range and the availability of charging facilities. Governments and manufacturers are increasingly aware of these factors, which have stimulated the development of charging infrastructure and advancements in battery technology. This heightened focus has had a positive impact on the growth trajectory of the entire market [10]. Government policies are also important in encouraging positive reinforcement. Subsidies, incentives, and investments in charging infrastructure that support NEVs encourage consumers to consider these vehicles. However, these rules are frequently meant to coexist with regular automobiles rather than completely replace them. This method assures that NEVs and traditional automobiles coexist in the market, contributing to the overall growth of the automotive sector [2]. In conclusion, the third perspective emphasises the idea that NEVs can have a positive reinforcement effect on the traditional automobile market. This is driven by modular production strategies, consumer purchasing behaviour, and government policies that promote the coexistence of NEVs and TFVs. Rather than being in direct competition, these two segments of the automobile market can complement each other, contributing to the growth and diversification of the industry.

3. Data analysis

This section aims to test the hypothesis that New Energy Vehicle (NEV) sales have a positive reinforcement on Traditional Fuel Vehicle (TFV) sales. The data, monthly production and sales data for both NEVs and the entire automobile market in China from January 2018 to the present, was collected from China's Ministry of Industry and Information Technology. An OLS regression analysis has been conducted on both national automobile production (sales) and NEV production (sales), respectively. Due to the observed differences between monthly production and sales figures, separate regression analyses have been performed for production and sales data to cross-validate the results. The outcomes are presented in Table 2.

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Table 2: Regression result

Variables	(1) ln(Autoproduction)	(2) ln(Autoproduction) (robust)	(3) ln(Autosales)	(4) ln(Autosales) (robust)
ln(NEVproduction)	0.146***	0.146*		
	(0.0349)	(0.0807)		
ln(NEVsales)			0.133***	0.133*
			(0.0345)	(0.0741)
Constant	4.927***	4.927***	4.974***	4.974***
	(0.109)	(0.266)	(0.108)	(0.245)
Observations	68	68	68	68
R-squared	0.210	0.210	0.183	0.183

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

As observed, there is a positive correlation between total automobile production and NEV production, which can be modelled as an exponential function of NEV production, with a power exponent of approximately 0.146. The 99% confidence interval for this result supports this relationship. It is important to note that, according to the characteristics of the function $y = x^{0.146}$, as NEV production increases, its positive reinforcement on the automobile market gradually diminishes. This observation aligns with real-world dynamics, as an increasing production of NEVs will eventually lead to market saturation. The situation regarding automobile sales and NEV sales mirrors that of production ones, with a slightly lower power exponent observed for sales data. This discrepancy may be attributed to the fact that sales data represent consumer purchases within the same month and are lagged, while production figures are based on manufacturers' expectations for the current month, considering previous months' trends, recent policies, and production cycles. As a result, the impact of NEV sales on overall market sales appears slightly less pronounced than the impact of NEV production on market production.

4. Conclusion

This paper has explored the intricate relationship between New Energy Vehicles (NEVs) and the entire automobile market, with a primary focus on identifying whether NEVs engender crowding-out effects or positive reinforcement. Our findings robustly indicate that NEVs exert a positive reinforcement effect on the overall automobile market. Firstly, NEVs have instigated significant transformations and innovations within the automotive sector. Modular production and the optimization of the industry's structure, driven by the unique attributes of NEVs, have yielded cost-effective solutions benefiting both NEVs and traditional fuel vehicles (TFVs). This shift has not only boosted industry efficiency but has also expanded production capacity, ultimately promoting growth across the market. Secondly, consumer behaviour plays a pivotal role in reinforcing the positive impact of NEVs. Many consumers view NEVs as suitable for short commutes and urban driving, often as secondary vehicles within their households. This consumer behaviour expands the market by addressing specific use cases while allowing TFVs to serve other needs, such as long-distance travel. NEVs have introduced new consumer segments and sales opportunities, contributing to overall market expansion. Moreover, heightened attention from governments and manufacturers to factors influencing consumer choices, like battery range and charging infrastructure, has further bolstered the positive impact on market growth. In essence, NEVs have coexisted harmoniously with TFVs, spurring innovation, optimizing production processes, and broadening the consumer base within the entire automobile industry. Rather than causing a decline in traditional vehicle sales, NEVs have acted

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as catalysts for positive change. As we move forward, continuous monitoring of this dynamic interplay will inform future policies and strategies for sustainable development.

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