A Car for Recognition: The Heterogeneous Market Responses to the Emergence of Electric Vehicles

Liu, Shimeng and Xu, Hangtian and Zhang, Wenqin and Zheng, Wenzhuo

Jinan University, Hunan University

1 May 2024

A Car for Recognition:

The Heterogeneous Market Responses to the Emergence of Electric Vehicles[#]

Shimeng Liu Hangtian Xu Wenqin Zhang Wenzhuo Zheng[*]

Abstract

In the automobile market, where consumers value the social recognition associated with car ownership, how would introducing a lower-cost alternative influence the market outcomes of traditional internal combustion engine vehicles (ICEVs)? Leveraging high-frequency sales data from China's entire automobile market from 2018 to 2022, we investigate the heterogeneous market responses to the emergence of electric vehicles (EVs) across different price-tier segments. Overall, the emergence of EVs reduces ICEV sales while boosting total automobile sales. More importantly, while EV penetration reduces ICEV sales in low- and mid-end segments, it enhances ICEV sales in the high-end segment. We provide further evidence that the rise of EVs amplifies the symbolic value of high-end ICEVs, resulting in improved sales for ICEV brands with strong social recognition.

Keywords: Electric Vehicle, Market Responses, Symbolic Value, Social Recognition

JEL codes: L16, L62, M2

[#] Acknowledgments: The authors gratefully acknowledge the financial support from the National Natural Science Foundation of China (grant numbers: 72373051; 72173038), the Ministry of Education of China (Project of Humanities and Social Sciences; grant number: 21YJC790133), and Guangdong Basic and Applied Basic Research Foundation (grant number: 2023A1515030117). The authors declare that they have no conflict of interest. The authors contributed equally to this work and are listed alphabetically. Please address all correspondence to Hangtian Xu.

[*] Shimeng Liu: Institute for Economic and Social Research, Jinan University, Guangzhou, P.R.C. (e-mail: shimengliu.econ@gmail.com). Hangtian Xu, Wenqin Zhang, and Wenzhuo Zheng: School of Economics and Trade, Hunan University, Changsha, P.R.C. (e-mail: hangtianxu@gmail.com (Xu); wenqinzhang@hnu.edu.cn (Zhang); wenzhuozheng@hnu.edu.cn (Zheng)).

1 INTRODUCTION

Beyond their practical purposes, many commodities also function as symbols of identity.[1] For instance, luxury handbags, watches, and cars often signify high social status due to their high prices. The demonstrative effect of such goods has emerged as a prominent factor behind consumers' acquisition of these commodities (Desmichel & Rucker, 2024; Han et al., 2010). In such markets where the symbolic representation of status through ownership is paramount, how would introducing a lower-cost alternative affect the market outcomes across different market segments? The answer to this question is highly relevant for firms in these industries, especially when facing competition from emerging technologies that offer greater economic efficiency, as well as for policymakers when designing industrial policies.

This paper sheds light on this question by exploring the heterogeneous market responses to the emergence of electric vehicles (EVs) within the automobile market in China. Possessing an automobile, particularly one from a prestigious brand, is widely regarded as a conspicuous marker of social status in China. However, the emergence of EVs has substantially reduced the entry threshold for automobile ownership, offering a more cost-effective alternative for prospective owners. Theoretically, a substantial substitution effect could arise between EVs and traditional internal combustion engine vehicles (ICEVs), considering the superior energy efficiency and lower per-mile and overall costs associated with EVs in contrast to ICEVs.[2]

On the other hand, the emergence of EVs may stimulate new demand by expanding the potential consumer base and inspiring households to diversify their automobile portfolios. The substitution and demand generation effects imply distinct predictions regarding the overall impact of EVs on the automobile market. More interestingly, the decreased expenses of EVs may attenuate the symbolic prestige traditionally linked with car ownership, resulting in varied reactions among consumers across different market segments. As a result,

[1] Aaker and Joachimsthaler (2000) define this function as a product's ability to "provide a vehicle by which a person can proclaim a particular self-image."

[2] We categorize automobiles into EVs and ICEVs based on their eligibility for a green license plate in China, which signifies a relatively high level of environmental friendliness. There are four types of EVs: Battery Electric Vehicles, Extended Range Electric Vehicles, Plug-in Hybrid Electric Vehicles, and Fuel Cell Vehicles. In addition to fossil fuel-based vehicles, Hybrid Electric Vehicles are classified as ICEVs due to their limited battery capacity and reliance on internal combustion engines.

interesting dynamics and heterogeneity could manifest in the automobile market as EVs emerge as viable lower-cost substitutes for ICEVs.

We leverage high-frequency sales data from China's entire automobile industry to explore the market reactions to the emergence of EVs across various price segments within the automobile market. We speculate that the emergence of EVs would lead to higher total automobile sales but lower ICEV sales. More importantly, the substitution effect of EVs can be more pronounced in lower-price market segments, where consumers are less interested in using cars as symbols of status and more focused on their intrinsic utility and cost efficiency. Meanwhile, due to the lower-costs of EVs, which to some extent diminishes their role as symbols of status, consumers who place greater value on the symbolic value of automobiles are then more inclined to purchase high-end ICEVs. Consequently, the market responses in the high-end market following the emergence of EVs depend on the relative strength between the substitution effect and the more pronounced social value of high-end ICEVs.

We formally propose a series of testable hypotheses and empirically examine them with carefully specified regression frameworks. Our baseline specification examines the impact of EV penetration on a set of market outcomes in the automobile market and across different price segments. To address potential endogeneity arising from unobserved intertemporal shocks that simultaneously affect EV penetration and the market outcomes of interest, we employ an instrumental variable (IV) estimation technique. We draw upon the recent development in econometrics and construct a Bartik-style shift-share IV as the interaction between the national cumulative EV penetration rate until last month (*the shift*) and a city's average January temperature (*the share*). The variation in winter temperature across cities provides exogenous variation in city-level EV penetration.

The results confirm our hypotheses, showing that the emergence of EVs increases overall automobile sales due to the market size effect, while simultaneously reducing ICEV sales due to the substitution effect. More importantly, we uncover important previously undiscovered heterogeneity across price-tier market segments. Specifically, the emergence of EVs reduces ICEV sales in lower-end segments but increases ICEV sales in the high-end segment. This finding implies the changes in customer perceptions of the symbolic prestige associated with automobiles following the emergence of EVs. We provide further evidence for the importance of the symbolic prestige by showing that only high-end ICEV brands with strong brand images and social recognition benefit from the emergence of EVs within the high-end market segment.

Our results offer compelling evidence that the rise of EVs amplifies the symbolic value of high-end ICEVs, resulting in improved sales for certain ICEV brands. Therefore, despite current trends indicating a potential technology replacement, especially if EV limitations in cold weather are resolved, the findings of this paper imply that ICEVs are unlikely to be fully replaced by EVs. Instead, ICEVs can continue to thrive in specific sub-markets. Adhering to ICEV manufacturing may thus represent an effective strategy for certain ICEV brands with strong social recognition. As leading EV manufacturers like Tesla keep their markdown pricing strategy, making EVs increasingly affordable, our conclusions will become more widely applicable to other countries where EVs are currently less cost-effective than in China.

2 LITERATURE

Our study mainly contributes to three strands of literature. First, this paper is closely related to a growing literature on status consumption, which explores the phenomenon of individuals purchasing goods for the social prestige they confer on their owners (Bellezza et al., 2014; Dion & Borraz, 2017; Escalas, 2013; Han et al., 2010; Mandel et al., 2006). Conspicuous goods, marked by their exclusivity and expense, serve to boost self-esteem and express identity (Veblen, 1899). Wealthy consumers often allocate significant spending on highly visible luxury items such as automobiles, fashion, and jewelry (Charles et al., 2009; Griskevicius & Kenrick, 2013; McFerran et al., 2014).

Because status signaling is a significant motivator for the consumption of conspicuous goods, many consumers perceive the price premium as an indicator of a status good's prestige value (Shapiro, 1983). Thus, the markdown pricing strategy may be sub-optimal when the proportion of high-end consumers is substantial (Arifoğlu et al., 2020; Nunes et al., 2011). Reduced prices may even alter consumer perceptions regarding the brands' status, prestige, and symbolic value (Yao, 2023). Amaral and Loken (2016) find that high-end consumers could value a luxury product less when more low-end consumers can afford it. Our results provide another piece of evidence for status consumption in a unique context where technological advancements lead the average price of a product to decline and cause consumers with status signaling motives to increasingly value products using the old technology but with a relatively stable high price.

Second, our work contributes to a burgeoning literature on the fate of old technology during technological advancements. The theory of disruptive change posits that when a new technology enters a market, it gradually improves in performance, surpasses the capabilities of the existing technology, and eventually replaces the old technology (Christensen, 2013; Tushman & Anderson, 1986). However, several prior studies challenge the prevailing view of the inevitable decline of old technologies following the introduction of new ones (Adner & Snow, 2010), attributing the potential for survival or even growth of old technologies to the underlying heterogeneity in customers' latent preference (Li, 2023; Nelson et al., 2023). Such heterogeneity can be driven by various factors, including budget constraints (Adner, 2002), preferences toward attributes of the old technology (Adner & Snow, 2010), and the desire to display identity and status (Mittal, 2006; Raffaelli, 2019). Those studies provide examples of the persistence or resurgence of old technology across diverse industries, including mechanical watches (Raffaelli, 2019), analog music synthesizers (Nelson et al., 2023), and traditional Chinese medicine (Li, 2023).[3]

Overall, the literature remains inconclusive regarding the relationship between the emergence of new technology and the fate of existing technology, leaving the optimal management strategy and government policy an open question. Our paper shows that the introduction of new technology can have divergent effects on the sales of products using older technology in the automobile industry, benefiting specific market segments or brands

[3] For instance, the emergence of quartz technology revealed a previously overlooked dimension of "mechanicalness" in watches, which Swiss manufacturers of mechanical watches leveraged to activate latent identity-related values. This strategic positioning enables them to thrive in the high-end market for an unexpectedly prolonged period (Raffaelli, 2019).

while damaging others. This important but previously undiscovered heterogeneity adds to the literature and offers valuable new insights for strategic decision-making for businesses and policymakers.

Finally, given our focus on the emergence of EVs, this paper naturally adds to the nascent literature on the impacts of EVs in the automobile market.[4] Because of EV's recent emergence, the literature has not reached a consensus regarding the impact of EVs on ICEVs and the broader automobile industry. For example, while Holland et al. (2021) suggest a substitution effect of EVs for ICEVs, Burlig et al. (2021) argue that EVs tend to complement existing ICEVs rather than replace them. The inconsistent results in the previous literature may be partly driven by the heterogeneity in preferences for EVs. Several studies have examined the heterogeneity in preferences for EVs across geographical regions, demographic groups, and periods (Forsythe et al., 2023; Gillingham et al., 2023). This paper systematically examines the impact of EV penetration on various categories of automobile sales and market composition across different price-tier market segments, which illustrates important heterogeneity in the impact of EVs and helps to reconcile the mixed conclusions in the literature.

3 BACKGROUND

3.1 Development and price decline of EVs in China

For a long time, China's global competitiveness in manufacturing ICEVs has been regarded as inadequate. To boost its global competitiveness and achieve a leapfrog in the automotive industry, China introduced substantial subsidy policies to encourage the development of EVs. The subsidies encompass support for both the industry and consumers. As an example of the subsidies to consumers, the subsidy for a typical EV buyer ranged from 25,000 to 55,000 yuan when the incentive program was first introduced nationwide (Ministry of Finance of China, 2015).[5]

[4] Another line of research studies how EV demand responds to various incentive programs (Beresteanu & Li, 2011; Hu et al., 2023), charging infrastructure subsidies (Shriver, 2015), gasoline and electricity prices (Bushnell et al., 2022), and local protection policies (Barwick et al., 2021).

[5] In addition to the nationwide subsidies provided by the central government, there were also city-specific and manufacturer-specific subsidies for car purchases. Unlike the central government subsidies, the intensity of these specific subsidies was considerably lower, and many subsidies were not exclusively targeted towards EVs.

Benefiting from robust government support, China's EV industry developed rapidly. Remarkably, within a few years, BYD Company Limited emerged as one of the world's leading EV manufacturers, while Contemporary Amperex Technology Company Limited (CATL) became the largest power battery supplier globally. A significant milestone in China's EV development occurred in early 2020 when BYD and CATL introduced upgraded batteries. The new battery greatly improved energy capacity and safety performance while maintaining affordability. Meanwhile, Tesla delivered the first batch of China-made Model 3 vehicles manufactured in Shanghai. Together, these new developments significantly expanded the production capacity of EVs and marked a breakthrough in core EV technology. With concerted efforts from the government and manufacturers, EV sales in China have surged since 2020 (Figure 1 Panel A). According to the IEA's *Global EV Outlook 2023*, EV sales in China accounted for approximately 60 percent of global EV sales by 2022.

Before 2020, EV manufacturers primarily targeted the mid- to high-range segments of the automobile market (Figure 1 Panel B). As the manufacturing cost dropped because of technological advancements, EVs quickly penetrated lower segments. As a salient example, in the segment priced below 50,000 yuan, over 60 percent of newly launched models were EVs in 2022, a significantly higher proportion compared to other segments. The heterogeneous market changes are also reflected in vehicle sales. The market segments priced below 50,000 yuan and between 50,000 and 100,000 yuan saw the largest increases in EV sales after 2020 (Figure 1 Panel A). Overall, we observe a trend of faster development in lower-priced segments of the EV market in China.

[Insert Figures 1 and 2 Here]

With the lower-priced segments experiencing faster growth, the Manufacturer's Suggested Retail Price (MSRP) of the cheapest EV models exhibited a clear downward trend from 2018 to 2022.[6] During the same period, the prices of ICEV models remained relatively stable. These price trends are illustrated in Figure 2, which presents the average MSRP of the lowest-priced EV and ICEV models separately for each year. The observed trends are

[6] The MSRP is the retail price recommended by manufacturers, which is sometimes informally referred to as the "sticker price."

consistent with the notion that decreasing costs, resulting from technological advancements in recent years, allow manufacturers to provide EV products at lower threshold prices.[7] In contrast, the price of ICEVs reached a plateau as ICEV technology has matured.

3.2 The symbolic prestige of automobiles in China

The Chinese automobile market is the world's largest. The annual number of newly registered automobiles has exceeded 20 million for ten consecutive years since 2014, reaching 24.56 million in 2023 (Ministry of Public Security of China, 2024). The desire for symbolic prestige plays a pivotal role in purchase decisions in this expansive market. For a long time, owning a car has been widely perceived as a symbol of status and financial well-being, and is often considered a prerequisite for marriage in urban China.

For Chinese consumers of high-end brand automobiles, the consideration of symbolic value can hold even greater significance. In a McKinsey & Company survey, nearly half of the respondents who own Audi, BMW, and Mercedes-Benz cars, the best-selling luxury brands in China, express a car-authority identity, and over half of the respondents acknowledge the brand image of these vehicles in China (McKinsey & Company, 2024). The strong symbolic attributes associated with specific brands or models can also foster brand loyalty. 40 percent of buyers who purchased cars priced over 300,000 yuan expressed their intention to choose the same brand for the next car (McKinsey & Company, 2021). These factors position Chinese customers as increasingly important in the global high-end car market.

Besides the need for symbolic prestige, the motivation to build a vehicle portfolio may also influence car purchases. Multi-vehicle households are increasingly common in China. In 2021, the proportion of multi-vehicle households among vehicle owners in China reached 30 percent (Yiche, 2023). This motive can contribute to the rise in EV sales, especially in the high-end segment, where customers often already own a traditional ICEV.

3.3 EVs' adaptability to low temperatures in China

[7] We observe similar price trends for popular EV models. For example, the Tesla Model 3 saw a continuous price decline from a range of 550,000 to 700,000 yuan in 2018 to between 230,000 and 330,000 yuan in 2023 (Online Appendix Figure OA1 Panel A). In the low-end segment, BYD cut the price of a popular EV model (Qin Plus DM-i plug-in hybrid) to a historic low of 79,800 yuan, proclaiming the slogan "EV is cheaper than ICEV."

Currently, the primary energy solutions used in EVs are ternary lithium batteries (TLBs) and lithium iron phosphate batteries (LFPBs). While TLBs outperform LFPBs in low temperatures, the performance of both types can be severely impaired in cold environments due to the degradation in charging and discharging power. In China, the use of LFPBs remains dominant for several reasons. First, China faces shortages of nickel and cobalt minerals, which are essential ingredients for TLB production. Second, LFPB offers a cost advantage compared to TLB. According to estimates from Cinda Securities in 2020, the overall cost of TLB is approximately 725 yuan per kilowatt-hour, while LFPB costs about 612 yuan (Electric New Scope, 2020). Third, the technological advancements in 2020 have propelled the development of LFPBs, substantially increasing their energy density and allowing their application in more scenarios.

[Insert Figure 3 Here]

Compared to EVs equipped with TLBs, EVs using LFPBs are more affected by cold weather. Therefore, battery performance at low temperatures is a crucial factor influencing consumers' willingness to buy EVs in China. Consequently, Chinese consumers in warmer regions would exhibit higher demand for EVs than consumers in colder regions, all else equal. This heterogeneity across regions implies an important correlation between EV penetration and winter temperatures. We depict this relationship in Figure 3, which plots the proportion of EV sales in total automobile sales against the average temperature in January at the city level. The pattern shows that EV penetration tends to be higher when a city's winter temperature is higher. This relationship provides vital exogenous variation for identification in our econometric model.

4 HYPOTHESES

Our analysis runs through three testable hypotheses. The first hypothesis speaks to how EV penetration affects a city's total automobile sales and ICEV sales. Previous studies find that new entrants incorporating new and improved technology tend to simultaneously cannibalize the sales of existing substitute products while expanding the relevant market (Chen et al., 2018; Xu et al., 2014). Similarly, the emergence of EVs could impose both a market share effect and a market size effect.

The market share effect comes from the substitution between EVs and ICEVs. The driving range of EVs has witnessed a substantial increase, while the production costs have declined, primarily due to technological advances in batteries. Moreover, the per-mile energy costs of EVs are substantially lower than that of ICEVs. These factors, along with improved charging infrastructure, make EVs viable substitutes for ICEVs in transportation (Holland et al., 2021). Thus, the emergence of EVs could shift a substantial portion of consumer demand from ICEVs to EVs, thereby cannibalizing the sales of ICEVs, which we refer to as a market share effect.

The market size effect arises because the emergence of EVs enriches consumers' choice sets, potentially stimulating higher demand and promoting automobile sales through two channels. First, it enables consumers to expand their vehicle portfolio (Johansen & Munk-Nielsen, 2022). Consumers often have preferences for portfolio goods that complement each other (Gentzkow, 2007). While EVs are perceived as not suitable for long-distance driving, they offer ICEV-owning households a more cost-effective and eco-friendly "second car" option, thereby catalyzing the proliferation of multi-car households. As a result, the complementarity in function and usage scenarios of EVs and ICEVs stimulates new demand from existing car owners.

Second, the introduction of EVs lowers the minimum price threshold for vehicle purchases, as discussed in the background section. This reduction in price threshold expands the potential consumer base, attracting individuals who were previously unable or unwilling to purchase a vehicle due to cost constraints. EVs' lower maintenance costs and higher energy efficiency further enhance their affordability advantage. As a result, the emergence of EVs can stimulate new demand from households previously constrained by budgetary limitations. Based on the above discussions, we summarize the first hypothesis as follows:

Hypothesis 1. *The emergence of EVs would lead to a decline in ICEV sales (market share effect) and an increase in total automobile sales (market size effect).*

Our second hypothesis concerns the heterogeneous impacts of EV penetration across different price-tier market segments. While EVs impose a substitution impact on overall ICEV sales, the impact in the high-end market segment can be more subtle. Cars are canonical status goods (Bricker et al., 2021), representing both instrumental values (e.g., a tool for convenient travel) and status-related social values (Dittmar, 1992). The latter is likely more prominent in the high-end market (Rucker & Galinsky, 2008). High-end automobile brands, which are often perceived as indicators of premium pricing and superior quality (Rao & Monroe, 1989), exhibit a greater capacity to communicate symbolic representations of consumers' values, accomplishments, and social status (Erickson & Johansson, 1985; Sengupta et al., 2002). Concurrently, consumers in the high-end segment demonstrate an elevated preference for the social and symbolic value associated with automobile ownership (Amaral & Loken, 2016).

However, the symbolic value of a luxury product can diminish when more lower-income people can afford it (Rao & Schaefer, 2013). Stated differently, a reduction in either the average expenditure necessary to acquire a product or the average income of consumers who own the product leads to a depreciation of its social value, potentially resulting in diminished willingness to pay for the product. With new technological advancements in EV production, the manufacturing costs of EVs have experienced a sharp downward trend after 2020. This cost advantage has translated into a substantial drop in EV prices, particularly for the minimum threshold price and the prices of entry-level models of high-end brands.[8] As EV prices drop and more people can afford cars, the symbolic value of EVs and low-end ICEVs can be eroded.[9]

More importantly, as more consumers substitute low-end ICEVs with cheaper EVs, the average price gap between sold EVs and ICEVs increases.[10] This trend is consequently

[8] For example, within several years, the entry-level prices of the Tesla Model 3 performance edition and basic edition have decreased from 698 thousand yuan to 329.9 thousand yuan, and from 339.9 thousand yuan to 259.9 thousand yuan, respectively (Online Appendix Figure OA1 Panel A).

[9] In contrast, ICEVs represent a mature technology with stable costs and a relatively rigid price system (Online Appendix Figure OA1 Panel B). In particular, high-end ICEVs have consistently employed a prestige pricing strategy, ensuring price stability that has endowed them with a "status-signaling attribute." In an interview, Michael Kirsch, President of Porsche China, emphasized the company's commitment to brand protection, stating that Porsche would not engage in price wars and would instead focus on maintaining its brand value and prestige (Wang & Guo, 2023).

[10] An increase in the sales of cheaper EV models reduces the average price of sold EVs. In contrast, a decrease in the sales of cheaper ICEV models boosts the average price of sold ICEVs. Online Appendix Figure OA3 illustrates that the average price gap between sold EVs and ICEVs widened after 2020.

projected to manifest in a corresponding divergence in the average income levels of EV and ICEV owners. The shift is likely to enhance the social value of ICEVs relative to EVs. Meanwhile, for high-end ICEV brands, their relatively cheaper ICEV models are more likely to be substituted by EV competitors. As a result, the average prices of sold cars from high-end ICEV brands are likely to increase, thereby boosting the social value of these high-end ICEV brands. Since consumers in the high-end segment place greater emphasis on the social value of cars, these factors are likely to drive more consumers in the high-end segment toward purchasing high-end ICEVs. In sum, we expect that the rapid EV penetration may change people's perception of different vehicles' symbolic value, prompting customers with a strong preference for social values to purchase high-end ICEVs. In Online Appendix B, we develop a simple conceptual framework to explain why EV penetration may increase the sales of high-end ICEVs in a slightly more formal manner.

Hypothesis 2. *While the emergence of EVs reduces overall ICEV sales, it may lead to higher ICEV sales in the high-end segment of the automobile market.*

The third hypothesis further considers the heterogeneity across different brands in the high-end market, which stems from the varying social value associated with different luxury brands. Hypothesis 2 is based on the logic that the rapid penetration of low-priced EVs may reduce the social value of EVs and low-end ICEVs while increasing the relative social value of high-end ICEVs. This factor can lead to higher ICEV sales in the high-end market segment. Naturally, this mechanism should more effectively promote the sales of high-end ICEV brands with a widely recognized and prestigious image. More recognized high-end brands should be more effective in displaying desirable social status to a broader audience. Of course, the social recognition of a specific high-end brand may exhibit regional heterogeneity. In cities where a high-end ICEV brand has successfully established a strong and widely recognized status-signaling value, the brand is more likely to grow and thrive despite the increasing EV penetration.

Hypothesis 3. *The emergence of EVs would more effectively promote the sales of high-end ICEV brands with higher social recognition.*

5 DATA AND METHOD

5.1 Data

The primary data utilized in our analysis comprise nationwide new vehicle registration records for passenger cars with up to nine seats, categorized by city, year-month of registration, and vehicle model, spanning the period between January 2018 and December 2022. The legal use of a new vehicle in China requires immediate compulsory registration upon purchase, with the acquisition of Statutory Automobile Liability Insurance (SALI) being a mandatory step of the registration process. We identify vehicle purchases through the SALI records. For each vehicle purchase, the database discloses its brand, model, origin (made in China or imported), purpose (e.g., sedan or sport utility), power system (e.g., diesel, electricity, or gasoline), and displacement range.

We aggregate sales for each model, resulting in a panel at the city-year-month-model level. Importantly, in our analysis, the EV and ICEV variants of the same model are considered as two independent models.[11] We exclude all methanol vehicle models, as they represent a distinct vehicle type separate from ICEVs and EVs, and their sales are negligible. We also exclude data from February 2020 due to the unusually low vehicle registration in that month caused by the pandemic outbreak, and data from 41 prefecture-level administrative units with missing Gross Domestic Product (GDP) information.[12] For any changes in cities' administrative divisions during our study period, we adjust the data accordingly to ensure consistency. In total, our data encompass vehicle registration of 1,787 models and 184 vehicle brands across 296 cities.

We also collect the MSRP of each vehicle model from *Dongchedi* (https://www.dongchedi.com/), China's leading automotive media and community platform providing professional automotive information, reviews, quotes, and other services. Specifically, we obtain the price range for each model and calculate the midpoint of the range to determine the price. We then categorize vehicle models and their associated brands into

[11] For example, the Tiguan, Volkswagen Passenger Cars' bestselling model, initially debuted as an engine-driven vehicle, but it now also has an electric edition available. We treat the EV and ICEV editions as two different models.

[12] The 41 prefecture-level administrative units include seven prefectures (e.g., Aksu Prefecture), three leagues (e.g., Alxa League), 30 autonomous prefectures (e.g., Aba Tibetan and Qiang Autonomous Prefecture), and the city of Sansha.

high-end, mid-end, and low-end segments based on the price. Specifically, models with prices below 150,000 yuan are classified as low-end, those priced between 150,000 and 350,000 yuan are considered mid-end, and those priced above 350,000 yuan are categorized as high-end (Deng & Ma, 2010).[13] Based on this classification, there are 113 brands in the low-end market (including 26 EVs-Only brands), 119 brands in the mid-end market (including 35 EVs-Only brands), and 54 brands in the high-end market (including 11 EVs-Only brands).

During the sample period, the MSRP of ICEV models remained stable, whereas the MSRP of certain EV models fluctuated greatly. For example, the MSRP of the Tesla Model 3 exceeded 500,000 yuan in 2018. However, after the commissioning of Tesla's Gigafactory in China, its price dropped to below 350,000 yuan (Online Appendix Figure OA1 Panel A). We use the MSRP in 2021−2022 as the benchmark for defining a model's price segment. Because there is little cross-city variation in a model's MSRP, we do not explore the MSRP responses to EV penetration.[14] Models priced over 3,000,000 yuan, most of which are ICEVs, are excluded from the analysis since they are not representative, and there is no EV counterpart in this price range.

We employ a set of complimentary datasets to construct the IV and control variables. City-level average temperatures are obtained from the National Center for Environmental Information (NCEI) of the United States. City-year-level control variables, including resident population, GDP per capita, the number of public buses in operation per capita, road area per capita, and the rate of centralized wastewater treatment, are extracted from the China City Statistical Yearbooks, China Urban Construction Statistical Yearbooks, and various local statistical yearbooks and statistical bulletins of provincial governments. The number of households owning vehicles valued at over 300,000 yuan in each province is derived from the Seventh National Population Census conducted in 2020. In addition, we obtain the quality reliability scores of vehicle brands from the website of *Consumer Reports*

[13] As an example, if the MSRP of the Basic Edition of a model is 200,000 yuan and the MSRP of the model's Deluxe/Performance Edition is 280,000 yuan, we calculate the model's MSRP as 240,000 ((200,000+280,000)/2) yuan. As a result, it is defined as a mid-end model.

[14] The effect of national-level MSRP changes is absorbed by the time fixed effects in our econometric specifications.

(https://www.consumerreports.org/), an independent nonprofit organization providing product information and ratings. Summary statistics are reported in Table OA1 in the Online Appendix.

5.2 Research design

We use the following econometric framework to estimate the market responses to EV penetration across different price segments of the automobile market:

$$Y_{i,t} = \alpha_0 + \alpha_1 EVshare_{i,t} + \alpha_2 X_{i,r} + \gamma_i + \lambda_t + \epsilon_{i,t}, \quad (1)$$

where i indexes cities, r indexes year, and t indexes year-month. $Y_{i,t}$ represents a series of market outcomes in the automobile market, including total vehicle sales, ICEV sales, EV sales, and the market share of different vehicle brands within price-tier submarkets. $EVshare_{i,t}$ denotes the cumulative penetration rate of EVs at the city-year-month level, which is defined as the cumulative share of EV sales until last month in city i's passenger vehicle market at time t.[15] Using this lagged cumulative measure not only mitigates potential simultaneity concerns but also better captures changes in the stock of cars on the road, which influence social recognition. $X_{i,r}$ is a set of city-year-level control variables, which are explained in detail below. γ_i and λ_t are city and year-month fixed effects, respectively. $\epsilon_{i,t}$ is the error term. We cluster standard errors at the city level to address possible serial correlation across periods (Bertrand et al., 2004).

We control for the following variables ($X_{i,r}$) in the specification: the natural logarithm of resident population, the natural logarithm of GDP per capita, the natural logarithm of the number of public buses in operation per 1,000 people, the natural logarithm of road area per capita, and centralized wastewater treatment rate. The centralized wastewater treatment rate can be considered as a proxy for a city's commitment to improving environmental quality. The remaining variables control for city economic factors that may affect the market outcomes in the automobile markets.

In addition, the city fixed effects control for time-invariant city-level unobservables,

[15] Specifically, this measure is calculated as the ratio of cumulative EV sales to cumulative passenger vehicle sales from January 2018 through the most recent month. We do not have sales data for 2017 or earlier, and there were very limited EVs sold in the market during that period.

such as electricity prices, which are region-specific but rarely change over time, and time-invariant city-level policies. The year-month fixed effects control for intertemporal macroeconomic shocks, such as the negative demand shock caused by the COVID-19 pandemic, changes in petrol/diesel prices, which fluctuate over time but have little variation across cities, and changes in the depreciation rate of EVs. It is worth noting that automobile prices exhibit little cross-city variation in China because its automobile market functions as a unified, highly integrated system with minimal regional segmentation. Thus, general price changes are effectively captured by the year-month fixed effects. Together, these control variables greatly alleviate concerns about omitted variable bias.

Despite the extensive control variables, estimating Equation (1) with ordinary least squares (OLS) may still lead to biased estimates. For example, unobserved intertemporal city-level shocks may simultaneously affect city-level EV penetration and the outcome variables of interest. We therefore construct a Bartik-style shift-share IV (Bartik, 1991; Goldsmith-Pinkham et al., 2020) and conduct two-stage least squares (2SLS) estimations to address any remaining endogeneity concerns. The instrument (*EVShare_N* × *Temp*) is the interaction between the national cumulative EV penetration rate until last month (*EVShare_N*) and a city's average temperature in January (*Temp*). The former can be considered as a common shock that changes over time but is homogeneous across cities (*the shift*), while the latter is city-specific and time-invariant, representing differential exposure to the common shock (*the share*). As discussed earlier, temperature is a key factor in EV performance, so warmer cities are subject to higher exposure to the shock from national EV penetration.

Based on Goldsmith-Pinkham et al. (2020), for the IV to be valid, it is sufficient for the *share* part of the IV, city-level January temperature (*Temp*), to be exogenous. That is, we need to justify that (i) *Temp* has a strong impact on *EVShare*, and (ii) *Temp* affects the changes in outcome variables only through its effect on *EVShare*. We present illustrative evidence for condition (i) in Figure 3 and provide further evidence based on formal regression analyses in Online Appendix A. For condition (ii), while climatic conditions can affect regional population and economic growth in the long run, we expect that the impact of temperature on unobserved social and economic changes is negligible within the several-year timeframe of this study, conditional on the comprehensive set of city-year-level control variables and fixed effects. Thus, the impact of temperature on changes in the outcome variables of interest is only through its impact on EV penetration, conditional on the control variables.

6 MAIN EMPIRICAL RESULTS

6.1 Market responses to EV penetration

In this subsection, we investigate the market responses to the emergence of EVs in the automobile market. Table 1 examines the impact of EV penetration on various categories of automobile sales. Panels A and B present the OLS and IV results for the entire passenger automobile market, respectively. Both panels suggest that EV penetration increases total auto sales and EV sales. Specifically, the IV results show that a one percentage point increase in EV penetration, represented by the cumulative share of EV sales until last month in a city's passenger vehicle market, leads to a 3.67 percent increase in total sales and a 21.40 percent increase in EV sales. The reduced cost of EV technology indeed induces more EV purchases and an expansion of the entire market. Meanwhile, EV penetration has a nonnegligible negative impact on ICEV sales, although the point estimate is statistically insignificant at the conventional level. Overall, the results confirm our Hypothesis 1 that the emergence of EVs leads to a decline in ICEV sales (market share effect) and an increase in total sales (market size effect).[16] In Column (1) of Panel B, we present the first-stage of IV estimation. The F-statistic is large, indicating a strong first-stage relationship, alleviating concerns regarding weak instrumental variables.[17]

Panels C−E of Table 1 present the IV results for low-, mid-, and high-end markets,

[16] We conduct two preliminary tests to provide evidence for the two mechanisms of the market size effect. First, in Online Appendix Table OA2, we show that EV penetration has a larger impact on EV sales in the high-end market in provinces with a higher share of households whose total vehicle value exceeds 300 thousand yuan in 2020. This result supports the notion that the emergence of EVs enables wealthy consumers to expand their vehicle portfolio. Second, in Online Appendix Table OA3, we further divide the low-end market into three segments: vehicles priced below 50 thousand yuan, between 50 thousand and 100 thousand yuan, and between 100 thousand and 150 thousand yuan. We find that EV penetration leads to a greater increase in EV sales in lower-price segments within the low-end market. This pattern is consistent with the notion that the reduction in the minimum price threshold stimulates new demand from individuals previously constrained by budgets.

[17] We present additional evidence of the important impact of temperature on EV penetration using an event-study specification in Online Appendix A.

respectively.[18] Unsurprisingly, EV penetration significantly boosts EV sales in all price-tier segments. In low- and mid-end markets, the increase in EV sales is accompanied by a reduction in ICEV sales, suggesting a strong substitution effect. The substitution is especially pronounced in the low-end market, where we observe a statistically significant negative impact on ICEV sales. The low-cost EV option seems to be especially valued by customers in the low-end market segment, where cost can be a dominant factor in purchase decisions. In contrast, in the high-end market, an increase in EV penetration boosts both EV and ICEV sales. Specifically, a one percentage point increase in EV penetration leads to a 4.97 percent increase in ICEV sales and a 21.23 percent increase in EV sales. The high-end market also expands as a whole with increased EV penetration. Specifically, when EV penetration increases by one percentage point, total automobile sales in the high-end market increase by 6.02 percent.

The finding that the development of EV technology seems to benefit, rather than harm, the sales of high-end ICEVs is particularly interesting. We posit that the decreased expenses of EVs and rapid EV penetration may attenuate the social value of EVs and low-end ICEVs. Meanwhile, it potentially enhances the social value of high-end ICEVs. As a result, individuals who value the symbolic representation of status through automobile ownership are more likely to purchase a high-end ICEV when EV penetration becomes high.[19] This impact compensates for the substitution effect and increases high-end ICEV sales. The results confirm our Hypothesis 2.

[Insert Table 1 Here]

6.2 Manufacturers' distinct strategy in the high-end market?

An alternative explanation for the unique market responses in the high-end market is that automobile manufacturers' market strategies differ in this segment.[20] We explore this

[18] Table OA4 in the Online Appendix presents the corresponding OLS results.

[19] Wang and Xing (2023) suggest that EV subsidies may induce low-quality firm entries and harm the collective reputation of EVs. This, in turn, may cause individuals to prefer ICEVs. However, in our sample period, the reduction in EV price is caused by improvement in EV technology and quality. Moreover, the collective reputation effect cannot explain the distince positive impact on high-end ICEVs.

[20] Note that any factors with a similar influence across different segments cannot be a viable alternative explanation. For example, public charging infrastructure may affect overall EV penetration and ICEV sales. However, since this factor affects low- and high-end markets similarly, it should not generate a differentiated impact across segments. Moreover, our control variables should have largely controlled for infrastructure differences across cities.

possibility in this subsection. In Panel A of Table 2, we report the total number of vehicle models and the proportion of EV models among them each year in each price-tier market segment. The statistics suggest that manufacturers actively developed EV models in all market segments during 2019−2022. Each year, the proportion of EV models developed in the high-end market is lower than that in the mid-end market but higher than that in the low-end market. It suggests that the earlier findings, indicating that EV penetration increased high-end ICEV sales, are not because manufacturers are less willing to pursue electrification transformation in the high-end segment.

In Panel B of Table 2, we present the average prices of the top 10 best-selling ICEV models nationwide for each year in each market segment. The statistics indicate that the prices of ICEV models remained stable during 2019−2022 in all segments. Thus, the increase in ICEV sales in the high-end market cannot be attributed to a markdown pricing strategy specific to this segment. Furthermore, the Chinese automobile market is highly integrated, with minimal price disparities across cities. Thus, even if manufacturers employed different pricing strategies across price-tier segments, such strategies cannot account for our findings in the high-end market based on city-level variations.[21]

In sum, the unique market responses in the high-end market are not a result of manufacturers' distinct market strategies in this segment. Ruling out the supply-side explanations provides further support for the demand-side explanation of changing perceptions of vehicles' social value in different market segments.

[Insert Tables 2 and 3 Here]

We provide further evidence for this issue through formal regression analyses. Table 3 examines the relationship between a brand's activeness in EV development and its subsequent market share within the corresponding price-tier segment. Specifically, we assess a brand's activeness in EV development by the proportion of its EV models relative to its total vehicle models. We measure this variable in 2018 to mitigate endogeneity concerns, considering it as a proxy for early EV engagement. The regression model is the following:

[21] The pricing strategy can only serve as a plausible alternative explanation if it varies across cities. However, the unified nature of the Chinese automobile market precludes such variations.

$$BMShare_{i,t,b} = \alpha_0 + \alpha_1 \, EVshare_{i,t} \times EV\_model\_2018_b + \gamma_{i,t} + \lambda_{t,b} + \mu_{i,b} + \epsilon_{i,t,b}, \quad (2)$$

where $BMShare_{i,t,b}$ denotes brand b's market share within its respective price-tier submarket in city i at year-month t. $\gamma_{i,t}$, $\lambda_{t,b}$ and $\mu_{i,b}$ are city-year-month, brand-year-month and city-brand fixed effects, which control for the impacts of economic factors and policy shocks at various levels. We use the interaction of the national cumulative EV penetration rate until last month (*EVShare_N*), a city's average January temperature, and the proportion of EV models in a brand's total models in 2018 ($EV\_model\_2018_b$) as the IV and conduct 2SLS estimation.

Columns (1) and (2) of Table 3 show that in low- and mid-end market segments, a brand's market share increases when it develops more EV models in its product mix. In contrast, Column (3) indicates that in the high-end segment, a brand's market share decreases when it develops more EV models. The results suggest that a brand's success in the high-end market is not bolstered, but rather hindered, by its active engagement in EV development. Given the findings from Table 2, which indicate that manufacturers pursue electrification transformation in the high-end market as actively as in the other segments, the pattern supports a demand-side explanation that consumers in the high-end market value symbolic prestige and are less receptive to EVs.

7 DO ALL BRANDS IN THE HIGH-END MARKET BENEFIT FROM EV SHOCK?

In this section, we explore which types of brands benefit from or are adversely affected by EV penetration. In Table 4, we categorize traditional automobile brands into mainstream and niche brands based on the 80/20 rule.[22] That is, we rank traditional brands based on their market shares within their respective price-tier segments between January 2018 and April 2020, a period before the surge in EV penetration. Then, we define the top brands that accounted for 80 percent of the market as mainstream brands, and the remaining brands as niche brands. We then investigate the differential impacts of EV penetration on the market shares of mainstream and niche brands in different price-tier segments in Columns (1) and (2) of Table 4.

[22] Traditional brands are defined in contrast to brands that are newly created solely to sell EVs.

The results show that an increase in EV penetration significantly reduces the market share of mainstream brands in the low- and mid-end markets, while the impacts on niche brands in those segments are small and statistically insignificant. In contrast, an increase in EV penetration sharply increases the market share of mainstream brands while reducing that of niche brands in the high-end market. Thus, while we previously found that EV penetration benefits the sales of both ICEVs and EVs in the high-end segment, the benefits are confined to mainstream brands, with niche brands being adversely affected. This finding is, again, more consistent with a demand-side explanation regarding changes in customers' perception of different brands' social value. With an increase in EV penetration, individuals who value the symbolic representation of status through automobile ownership are more likely to purchase mainstream brands that are more widely recognized.

We also study the impacts of EV penetration on the market share of EVs-only brands in Columns (3) of Table 4. EVs-only brands are non-traditional brands that exclusively produce EVs. EV penetration significantly boosts the market share of EVs-only brands in the low- and mid-end markets, but the impact in the high-end market is small and marginally significant. This small impact on EVs-only brands in the high-end market, again, implies that consumers in the high-end market are less receptive to EVs.

[Insert Tables 4 and 5 Here]

In Table 5, we separately estimate the impacts of EV penetration on the market shares of ICEV models and EV models for mainstream brands and niche brands. Column (1) suggests that for mainstream brands, an increase in EV penetration reduces the market share of ICEV models in the low- and mid-end markets, but boosts that in the high-end market. For comparison, Column (3) shows that for mainstream brands, an increase in EV penetration increases the market share of EV models in all segments, but the increase is much smaller in the mid- and high-end segments. Importantly, the positive impact of EV penetration on the market share of ICEV models is much larger than that of EV models in the high-end segment. Thus, the positive impact of EV penetration on the overall market share of mainstream brands in the high-end market is mostly driven by its positive impact on the market share of ICEV models. Similarly, the negative impact of EV penetration on the overall market share of mainstream brands in the low- and mid-end segments is mainly driven by its negative impact on the market share of ICEV models.

We also study the impact of EV penetration on ICEV and EV models for niche brands in Columns (2) and (4) of Table 5. For niche brands, EV penetration reduces the market share of ICEV models while increasing the market share of EV models in all market segments. In the low- and mid-end segments, the positive impact on EV models and the negative impact on ICEV models mostly cancel each other out, leading the overall impact on the market shares of niche brands in those segments to be small and statistically insignificant in Table 4. In the high-end market, the negative impact on ICEV models predominates, causing an overall negative impact of EV penetration on the market shares of niche brands.

In sum, the primary driver of the positive impact of EV penetration on high-end ICEV sales is the increased popularity of high-end ICEV models of mainstream brands.[23] The results, once again, align with a demand-side explanation regarding changes in customer perceptions of different vehicles' social value. The mainstream brands, which were closely tied to social status before the EV shock, are increasingly perceived as classic and high-end as cheaper EV options become prevalent.

Importantly, the comparison between mainstream and niche brands serves to rule out many alternative explanations. For example, one may think that customers in the high-end segment have higher time costs and value the safety and convenience of ICEVs more than customers in other segments. These factors may potentially explain the positive impact of EV penetration on the overall high-end ICEV sales in Table 1. However, since these factors apply equally to both mainstream and niche brands, they cannot account for the distinct positive impact on sales of ICEV models of mainstream brands. Similarly, any factors that apply equally to mainstream and niche brands in the high-end market cannot serve as a potential

[23] In Online Appendix Table OA5, we report the total number of vehicle models and the proportion of EV models for mainstream and niche brands each year across price-tier market segments. Niche brands developed EV models more actively than mainstream brands, suggesting that niche brands may employ different strategies compared to mainstream brands. However, we observe similar intertemporal trends in the proportion of EV models among all models in all market segments for mainstream and niche brands. This suggests that the distinct impact of EV penetration on ICEV sales of mainstream brands in the high-end segment, compared to other segments, is not driven by differing strategies between mainstream and niche brands in this segment.

explanation. The comparision provides evidence that the emergence of EVs would more effectively promote the sales of high-end ICEV brands with a widely recognized and prestigious image, which confirms our Hypothesis 3.[24]

Our findings contribute to an important debate about whether incumbent firms should adopt new technology or stick with the old technology when faced with threats from a new, potentially more cost-efficient technology (Chandrasekaran et al., 2022). The findings support the view that, in some markets, the emergence of a new technology may reveal latent customer preferences for attributes of the old technology that are lessened by the new technology. In such cases, sticking with the old technology may be an effective strategy that enhances sales performance for a particular set of firms (Adner & Snow, 2010; Li, 2023; Raffaelli, 2019).[25] In our case, sticking with ICEVs is an effective strategy for high-end mainstream brands. As EVs become more prevalent, the association between automobiles and social status weakens, making high-end ICEVs more appealing to customers who highly value symbolic prestige and possess high purchasing power.

8 DISCUSSION AND CONCLUSION

When confronted with a lower-cost new technology in the automobile market, how should automobile manufacturers strategize to enhance sales performance? The current literature generally favors a path of timely transition from the old to the new technology (Adner & Snow, 2010; Christensen, 2013). Our study intends to provide a more comprehensive answer to this inquiry by systematically examining the relationship between the emergence of EVs and the market position of ICEVs. Specifically, by leveraging high-frequency sales data encompassing the entire automobile industry in China from 2018 to 2022, we investigate the heterogeneous market responses to the emergence of EVs across different price-tier segments within the Chinese automobile market.

Overall, the emergence of EVs reduces ICEV sales while boosting total automobile sales. More importantly, we uncover previously undiscovered heterogeneity in the market

[24] We corroborate the robustness of this finding using two alternative proxies for brand value and customer recognition, which are shown in Online Appendix D.

[25] Another example is the emergence of quartz watches, which initially led to a decline in demand for mechanical watches, relegating them to a niche market. However, Swiss mechanical watch manufacturers later experienced a significant and unexpected increase in revenue, even surpassing that of quartz watch manufacturers (Raffaelli, 2019).

responses: While EV penetration reduces ICEV sales in low- and mid-end segments, it enhances ICEV sales in the high-end segment. We further illustrate that only high-end ICEV brands endowed with robust brand images and social recognition benefit from the emergence of EVs within the high-end segment. The results provide compelling evidence that the rise of EVs amplifies the social value of high-end ICEVs, resulting in improved sales for select ICEV models.

Our results provide valuable insights into market acquisition strategies for manufacturers. Despite all traditional ICEV manufacturers having launched EV models, there is significant heterogeneity in their enthusiasm toward electrification. This indicates a shared recognition of the necessity for electrification transformation, yet diversity in manufacturers' product strategies. With continual technological advancements in EVs, firms sticking to the old technology risk being relegated to a niche market. However, our results indicate that this does not necessarily lead to worse performance for those firms.

In particular, the rise of EV technology may reveal latent consumer preference over attributes associated with ICEVs (Li, 2023). While EV technology is rapidly evolving, leading to reductions in production costs and prices, there is little expectation of dramatic upgrades in the classic and sophisticated technology of internal combustion engines. Therefore, a popular view is that EVs will soon dominate the preferences of price-sensitive low-income households. In a market where owning luxury cars carries social values, the emergence of EVs enhances the preference for ICEVs in the high-end market. As a result, contrary to the common view of technological replacement, maintaining ICEV manufacturing may prove to be an effective strategy for certain ICEV brands with robust social recognition. These findings also offer valuable implications for policymakers in formulating industrial strategies and evaluating competitive advantages across different segments of the value chain.

We acknowledge some limitations of this study when generalizing its findings. The conclusions of the current study are based on five years of data. From a technological cycle standpoint, the market demand for certain legacy technologies—products like sailing ships, vinyl records, and mechanical watches—typically experiences an initial decline followed by a resurgence once new technologies are introduced (Raffaelli, 2019). Our findings provide some indication that ICEVs may follow a similar trajectory, but the timeframe of this study is insufficient to definitively ascertain this conclusion. Furthermore, this study is confined to a single country, though its substantial size makes it a worthy subject of research. However, despite these limitations, our results are expected to maintain their relevance beyond the short term and a single country. A recent survey by the China Association of Automobile Manufacturers reveals low acceptance of EVs among high-end consumers in China, despite the country's overall EV penetration rate approaching 40 percent. The pattern suggests our findings is likely to be relevant for a long time. Moreover, the global acceleration of EV adoption indicates that our findings will have broad geographical applicability.

REFERENCES

Aaker, D. A., & Joachimsthaler, E. (2000). The brand relationship spectrum: the key to the brand architecture challenge. *California Management Review*, *42*(4), 8−23.

Adner, R. (2002). When are technologies disruptive? A demand-based view of the emergence of competition. *Strategic Management Journal*, *23*(8), 667–688.

Adner, R., & Snow, D. (2010). Old technology responses to new technology threats: Demand heterogeneity and technology retreats. *Industrial and Corporate Change*, *19*(5), 1655–1675.

Amaral, N. B., & Loken, B. (2016). Viewing usage of counterfeit luxury goods: Social identity and social hierarchy effects on dilution and enhancement of genuine luxury brands. *Journal of Consumer Psychology*, *26*(4), 483–495.

Arifoğlu, K., Deo, S., & Iravani, S. M. (2020). Markdowns in seasonal conspicuous goods. *Marketing Science*, *39*(5), 1016–1029.

Bartik, T. J. (1991). Who benefits from state and local economic development policies? W. E. Upjohn Institute for Employment Research.

Barwick, P. J., Cao, S., & Li, S. (2021). Local protectionism, market structure, and social welfare: China's automobile market. *American Economic Journal: Economic Policy*, *13*(4), 112–151.

Bellezza, S., Gino, F., & Keinan, A. (2014). The red sneakers effect: Inferring status and competence from signals of nonconformity. *Journal of Consumer Research*, *41*(1), 35–54.

Beresteanu, A., & Li, S. (2011). Gasoline prices, government support, and the demand for hybrid vehicles in the United States. *International Economic Review*, *52*(1), 161–182.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics*, *119*(1), 249–275.

Bricker, J., Krimmel, J., & Ramcharan, R. (2021). Signaling status: The impact of relative income on household consumption and financial decisions. *Management Science*, *67*(4), 1993–2009.

Burlig, F., Bushnell, J., Rapson, D., & Wolfram, C. (2021). Low energy: Estimating electric vehicle electricity use. *AEA Papers and Proceedings*, *111*, 430–435.

Bushnell, J. B., Muehlegger, E., & Rapson, D. S. (2022). Energy prices and electric vehicle adoption. NBER working paper 29842, National Bureau of Economic Research. Available at: https://www.nber.org/papers/w29842.

Chandrasekaran, D., Tellis, G. J., & James, G. M. (2022). Leapfrogging, cannibalization, and survival during disruptive technological change: The critical role of rate of disengagement. *Journal of Marketing*, *86*(1), 149–166.

Charles, K. K., Hurst, E., & Roussanov, N. (2009). Conspicuous consumption and race. *The Quarterly Journal of Economics*, *124*(2), 425–467.

Chen, H., Hu, Y. J., & Smith, M. D. (2018). The impact of E-book distribution on print sales: Analysis of a natural experiment. *Management Science*, *65*(1), 19–31.

Christensen, C. M. (2013). *The innovator's dilemma: When new technologies cause great firms to fail*. Boston: Harvard Business Review Press.

Deng, H., & Ma, A. C. (2010). Market structure and pricing strategy of China's automobile industry. *The Journal of Industrial Economics*, *58*(4), 818–845.

Desmichel, P., & Rucker, D. D. (2024). Dominance versus prestige hierarchies: How social hierarchy base shapes conspicuous consumption. *Journal of Consumer Research*, *50*(5), 887–906.

Dion, D., & Borraz, S. (2017). Managing status: How luxury brands shape class subjectivities in the service encounter. *Journal of Marketing*, *81*(5), 67–85.

Dittmar, H. (1992). *The social psychology of material possessions: To have is to be.* New York: Hemel Hampstead, Harvester Wheatsheaf & St Martin's Press.

Electric New Scope (2020). The cost competition between TLB and LFPB: Which one takes the lead? (in Chinese). Retrieved from https://www.dongchedi.com/article/6907460349281239556.

Erickson, G. M., & Johansson, J. K. (1985). The role of price in multi-attribute product evaluations. *Journal of Consumer Research*, *12*(2), 195–199.

Escalas, J. (2013). Self-identity and consumer behavior. *Journal of Consumer Research*, *39*(5), xv–xviii.

Forsythe, C. R., Gillingham, K. T., Michalek, J. J., & Whitefoot, K. S. (2023). Technology advancement is driving electric vehicle adoption. *Proceedings of the National Academy of Sciences*, *120*(23), e2219396120.

Gentzkow, M. (2007). Valuing new goods in a model with complementarity: Online newspapers. *American Economic Review*, *97*(3), 713–744.

Gillingham, K. T., van Benthem, A. A., Weber, S., Saafi, M. A., & He, X. (2023). Has consumer acceptance of electric vehicles been increasing? Evidence from microdata on every new vehicle sale in the United States. *AEA Papers and Proceedings*, *113*, 329–335.

Goldsmith-Pinkham, P., Sorkin, I., & Swift, H. (2020). Bartik instruments: What, when, why, and how. *American Economic Review*, *110*(8), 2586–2624.

Griskevicius, V., & Kenrick, D. T. (2013). Fundamental motives: How evolutionary needs influence consumer behavior. *Journal of Consumer Psychology*, *23*(3), 372–386.

Han, Y. J., Nunes, J. C., & Drèze, X. (2010). Signaling status with luxury goods: The role of brand prominence. *Journal of Marketing*, *74*(4), 15–30.

Holland, S. P., Mansur, E. T., & Yates, A. J. (2021). The electric vehicle transition and the economics of banning gasoline vehicles. *American Economic Journal: Economic Policy*, *13*(3), 316–344.

Hu, Y., Yin, H., & Zhao, L. (2023). Subsidy phase-out and consumer demand dynamics: Evidence from the battery electric vehicle market in China. *Review of Economics and Statistics*, 1–50.

International Energy Agency (2023). Global EV Outlook 2023. Retrieved from https://www.iea.org/reports/global-ev-outlook-2023.

Johansen, B. G., & Munk-Nielsen, A. (2022). Portfolio complementarities and electric vehicle adoption. Working paper.

Li, X. (2023). When firms may benefit from sticking with an old technology. *Strategic Management Journal*, *45*(3), 399–428.

Mandel, N., Petrova, P. K., & Cialdini, R. B. (2006). Images of success and the preference for luxury brands. *Journal of Consumer Psychology*, *16*(1), 57–69.

McFerran, B., Aquino, K., & Tracy, J. L. (2014). Evidence for two facets of pride in consumption: Findings from luxury brands. *Journal of Consumer Psychology*, *24*(4), 455–471.

McKinsey & Company (2021). McKinsey China auto consumer insights 2021 (in Chinese).

McKinsey & Company (2024). McKinsey China auto consumer insights 2024. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mckinsey-china-auto-consumer-insights-2024.

Ministry of Finance of China (2015). Announcement of the New Energy Vehicle subsidy policy in China from 2016 to 2020 (in Chinese). Retrieved from https://www.gov.cn/xinwen/2015-04/29/content_2855040.htm.

Ministry of Public Security of China (2024). Announcement of car ownership in China (in Chinese). Retrieved from https://www.gov.cn/lianbo/bumen/202401/content_6925362.htm.

Mittal, B. (2006). I, me, and mine — how products become consumers' extended selves. *Journal of Consumer Behaviour*, *5*(6), 550–562.

Nelson, A., Anthony, C., & Tripsas, M. (2023). "If I could turn back time": Occupational dynamics, technology trajectories, and the reemergence of the analog music synthesizer. *Administrative Science Quarterly*, *68*(2), 551–599.

Nunes, J. C., Drèze, X., & Han, Y. J. (2011). Conspicuous consumption in a recession: Toning it down or turning it up? *Journal of Consumer Psychology*, *21*(2), 199–205.

Raffaelli, R. (2019). Technology reemergence: Creating new value for old technologies in Swiss mechanical watchmaking, 1970–2008. *Administrative Science Quarterly*, *64*(3), 576–618.

Rao, A. R., & Monroe, K. B. (1989). The effect of price, brand name, and store name on buyers' perceptions of product quality: An integrative review. *Journal of Marketing Research*, *26*(3), 351–357.

Rao, R. S., & Schaefer, R. (2013). Conspicuous consumption and dynamic pricing. *Marketing Science*, *32*(5), 786–804.

Rucker, D. D., & Galinsky, A. D. (2008). Desire to acquire: Powerlessness and compensatory consumption. *Journal of Consumer Research*, *35*(2), 257–267.

Sengupta, J., Dahl, D. W., & Gorn, G. J. (2002). Misrepresentation in the consumer context. *Journal of Consumer Psychology*, *12*(2), 69–79.

Shapiro, C. (1983). Premiums for high quality products as returns to reputations. *The Quarterly Journal of Economics*, *98*(4), 659–679.

Shriver, S. K. (2015). Network effects in alternative fuel adoption: Empirical analysis of the market for ethanol. *Marketing Science*, *34*(1), 78–97.

Tushman, M. L., & Anderson, P. (1986). Technological discontinuities and organizational environments. *Administrative Science Quarterly*, 31, 439–465.

Veblen, T. (1899). The theory of the leisure class. New York: Penguin.

Wang, J., & Guo, Y. (2023). Five automakers firmly resist cutting prices amid the intensifying price war in the Chinese automobile market (in Chinese). Retrieved from https://finance.sina.com.cn/stock/roll/2023-03-15/doc-imykxtwz3225649.shtml.

Wang, J., & Xing, J. (2023). Subsidizing industry growth in a market with lemons: Evidence from the Chinese electric vehicle market. *SSRN Electronic Journal*.

Xu, J., Forman, C., Kim, J. B., & van Ittersum, K. (2014). News media channels: Complements or substitutes? Evidence from mobile phone usage. *Journal of Marketing*, *78*(4), 97–112.

Yao, A. (2023). Uncovering heterogeneous prestige effect in luxury consumption: Insights from the Chinese luxury market. *Journal of Business Research*, 168, 114235.

Yiche (2023). Multi-vehicle households, the new blue ocean in China's automobile market amid the era of stock competition (in Chinese). Retrieved from https://news.yiche.com/hao/wenzhang/84793561/.

TABLES AND FIGURES

TABLE 1 The impact of EV penetration on automobile sales

	(1) EVShare	(2) ln(TotalSale)	(3) ln(ICEVSale)	(4) ln(EVSale)
Panel A: All markets (OLS)				
EVShare		2.200***	-0.467	4.136***
		(0.508)	(0.548)	(1.244)
N		17,444	17,444	17,444
Dep. Var. Mean before April 2020		5766.49	5522.20	244.29
Panel B: All markets (2SLS)				
Temp × EVShare_N	0.0299***			
	(0.00250)			
EVShare		3.671***	-0.669	21.395***
		(1.006)	(1.002)	(3.322)
N	17,444	17,444	17,444	17,444
Kleibergen-Paap F-stat.	143.23			
Dep. Var. Mean before April 2020		5766.49	5522.20	244.29
Panel C: Low-end market (2SLS)				
EVShare		2.468**	-2.169**	23.657***
		(1.010)	(1.032)	(3.950)
N		17,444	17,444	17,444
Dep. Var. Mean before April 2020		3062.00	2969.49	92.51
Panel D: Mid-end market (2SLS)				
EVShare		3.399***	-0.743	24.594***
		(1.242)	(1.185)	(3.495)
N		17,444	17,444	17,444
Dep. Var. Mean before April 2020		1926.14	1795.91	130.23
Panel E: High-end market (2SLS)				
EVShare		6.023***	4.971***	21.231***
		(1.347)	(1.406)	(2.716)
N		17,444	17,444	17,444
Dep. Var. Mean before April 2020		778.35	756.81	21.54
City-Year Level Controls	Y	Y	Y	Y
City FEs	Y	Y	Y	Y
Year-Month FEs	Y	Y	Y	Y

NOTES: Panel A and Panels B−E report the ordinary least squares (OLS) and two-stage least squares (2SLS) estimation results of the impact of EV penetration on vehicle sales, respectively. Column 1 of Panel B reports the first-stage results of the 2SLS estimation. The instrument (*Temp × EVShare_N*) is the interaction between the national cumulative EV penetration rate until last month (*EVShare_N*) and a city's average temperature in January (*Temp*). The dependent variables in Columns 2 to 4 are total vehicle sales, ICEV sales, and EV sales, respectively. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020 before taking the log. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 2 Manufacturer strategies across market segments

Panel A	Total number of models (Proportion of EV models)				
Market Segment	2018	2019	2020	2021	2022
Low-end	588 (0.11)	591 (0.16)	514 (0.19)	475 (0.24)	439 (0.25)
Mid-end	319 (0.32)	369 (0.39)	381 (0.44)	438 (0.47)	455 (0.50)
High-end	206 (0.14)	215 (0.17)	200 (0.23)	210 (0.27)	228 (0.33)
Panel B	Average price of ICEV models (in thousand yuan) (Percentage change from the previous year)				
Market Segment	2018	2019	2020	2021	2022
Low-end	109.46	110.19 (0.66)	108.88 (-1.19)	105.83 (-2.80)	107.24 (1.33)
Mid-end	194.84	193.06 (-0.91)	192.88 (-0.09)	193.11 (0.12)	189.04 (-2.11)
High-end	583.73	570.77 (-2.22)	577.22 (1.13)	583.15 (1.03)	580.31 (-0.49)

NOTES: Panel A presents the total number of vehicle models and the proportion of EV models among all models for each year across price-tier market segments, with the proportion of EV models displayed in parentheses. Panel B reports the average prices (in thousand yuan) of the top 10 best-selling ICEV models nationwide for each year in each market segment, with the percentage change in price from the previous year shown in parentheses.

TABLE 3 Brand activeness in EV development and market share

Price-Tier Market Segment	(1) Low-end	(2) Mid-end	(3) High-end
Panel A: 2SLS	Brand Market Share (*BMShare*)		
EVShare × EVmodel2018	0.121***	0.0539***	-0.738***
	(0.0278)	(0.0196)	(0.234)
N	1,077,654	996,029	437,676
Dep. Var. Mean before April 2020	0.0147	0.0155	0.0336
Panel B: First-stage	EVShare × EVmodel2018		
Temp × EVShare_N × EVmodel2018	0.0312***	0.0309***	0.0358***
	(0.00308)	(0.00347)	(0.00676)
N	1,077,654	996,029	437,676
Kleibergen-Paap F-stat.	102.46	79.34	28.11
City × Year-Month FEs	Y	Y	Y
City × Brand FEs	Y	Y	Y
Year-Month × Brand FEs	Y	Y	Y

NOTES: This table explores the relationship between a brand's activeness in EV development and its subsequent market share. Observations are at the year-month-city-brand level. The dependent variable is a brand's market share within its respective price-tier segment (*BMShare*). *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. *EVmodel2018* denotes the proportion of EV models among a brand's total vehicle models in 2018. The instrument (*Temp* × *EVShare_N* × *EVmodel2018*) is the interaction of a city's average January temperature, national cumulative EV penetration rate until previous month, and the proportion of EV models among a brand's total models in 2018. The regressions control for city-year-level characteristics, city-year-month fixed effects, city-brand fixed effects, and year-month-brand fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 4 EV penetration and market share of mainstream, niche and EVs-Only brands

	(1)	(2)	(3)
		Market Share of # Brands	
	Mainstream	Niche	EVs-Only
Panel A: Low-end market			
EVShare	-1.110***	-0.0283	1.139***
	(0.220)	(0.215)	(0.0859)
N	17,418	17,418	17,418
D.V. Mean pre-April 2020	0.805	0.191	0.00407
Panel B: Mid-end market			
EVShare	-2.118***	-0.128	2.246***
	(0.256)	(0.206)	(0.185)
N	17,411	17,411	17,411
D.V. Mean pre-April 2020	0.795	0.194	0.0113
Panel C: High-end market			
EVShare	2.064***	-2.258***	0.193*
	(0.493)	(0.459)	(0.117)
N	17,361	17,361	17,361
D.V. Mean pre-April 2020	0.779	0.215	0.00573

NOTES: The dependent variables in Columns 1 to 3 are the market shares of mainstream, niche, and EVs-Only brands in their respective price-tier segments, respectively. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. In each price-tier submarket, mainstream and niche brands are defined using the 80/20 rule, based on their market shares within their respective price-tier segments between 2018 and 2020. We define the top brands that accounted for 80 percent of the market as mainstream brands, and the remaining as niche brands. EVs-only are non-traditional brands that exclusively produce EVs. The regressions control for city-year-level characteristics, city and year-month fixed effects. We also report the mean value of the dependent variables before April 2020. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 5 EV penetration and market share of ICEV and EV models for specific brands

	(1)	(2)	(3)	(4)
		Market Share of #		
	ICEV Mainstream	ICEV Niche	EV Mainstream	EV Niche
Panel A: Low-end market				
EVShare	-2.913***	-0.766***	1.802***	0.738***
	(0.259)	(0.221)	(0.183)	(0.0661)
N	17,418	17,418	17,418	17,418
D.V. Mean pre-April 2020	0.801	0.184	0.00443	0.00711
Panel B: Mid-end market				
EVShare	-2.360***	-0.784***	0.242***	0.656***
	(0.262)	(0.178)	(0.0375)	(0.145)
N	17,411	17,411	17,411	17,411
D.V. Mean pre-April 2020	0.790	0.181	0.00527	0.0123
Panel C: High-end market				
EVShare	1.754***	-2.618***	0.310***	0.360***
	(0.475)	(0.441)	(0.0456)	(0.118)
N	17,361	17,361	17,361	17,361
D.V. Mean pre-April 2020	0.775	0.214	0.00403	0.000460

NOTES: The dependent variables in Columns 1 to 4 are the market share of ICEV models of mainstream brands, the market share of ICEV models of niche brands, the market share of EV models of mainstream brands, and the market share of EV models of niche brands, respectively. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. We also report the mean value of the dependent variables before April 2020. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

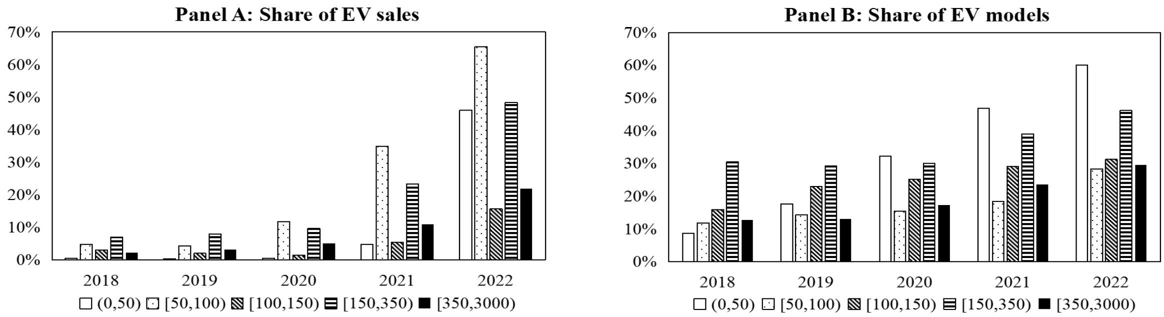

FIGURE 1 Share of EV models and EV sales across price tiers

NOTES: Panel A displays the proportion of EV sales in total vehicle sales in each price tier each year. Panel B presents the proportion of EV models among newly launched automobile models in each price tier each year. We categorize vehicle models into five price tiers based on their MSRPs, as shown in the legend. The MSRPs are in units of thousand yuan. For instance, (0,50) means the price range of models below 50,000 yuan.

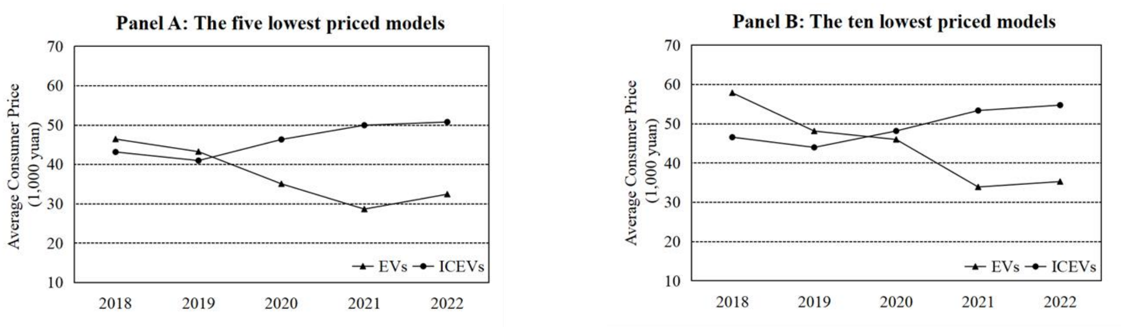

FIGURE 2 Average prices of the lowest-priced vehicle models

NOTES: Panel A presents the average MSRP of the five lowest-priced EV and ICEV models each year from 2018 to 2022, and Panel B shows the price patterns for the 10 lowest-priced models.

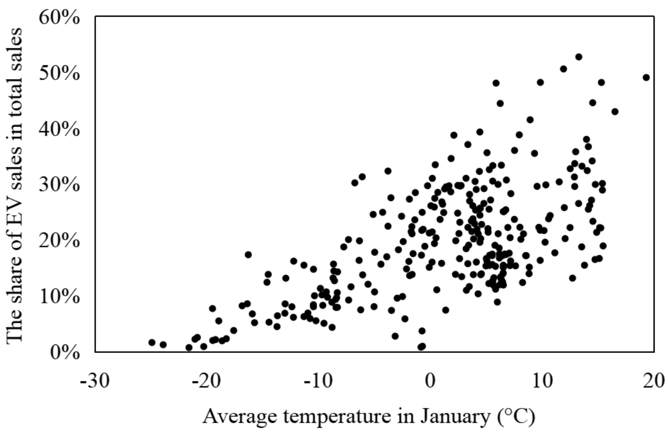

FIGURE 3 The influence of temperature on EV adoption

NOTES: This figure displays the relationship between the average temperature in January (in degrees Celsius) and the share of EV sales in total automobile sales at the city level in 2022.

Online Appendix to:

A Car for Recognition: The Heterogeneous Market Responses to the Emergence of Electric Vehicles

(NOT for Publication)

Table of Content

A. The impact of temperature on EV penetration

To formally demonstrate the impact of temperature on EV penetration and illustrate the timing of this impact, we examine the dynamic impact of a city's January temperature on the monthly market share of EV sales with an event-study specification. The regression equation is the following:

$$EVsharecur_{i,t} = \alpha_0 + \sum_{t=1}^{59} \alpha_t Temp_i \times D_t + \alpha_m X_{i,r} + \gamma_i + \lambda_t + \epsilon_{i,t},$$

where D_t is a set of year-month dummies from January 2018 (t = 1) to December 2022 (t = 59). $EVsharecur_{i,t}$ denotes the share of EV sales in the passenger vehicle market for the current month in city i and time t. There are 59 months in total because we excluded the data from February 2020, as the outbreak of COVID-19 caused the national car sales to plummet to almost zero that month. We omit the dummy for April 2020 (t = 27), which serves as the benchmark period. Other variables are defined the same as in Equation (1) in the main text.

We use April 2020 as the benchmark period for two reasons. First, the technological advancements in early 2020 were a major factor in the rapid growth of EV sales in the Chinese market. Second, the months before April are considered the off-season for car sales in China because of the Lunar New Year holidays. We expect α_t to be significantly positive after April 2020 (i.e., $t > 27$), as the EV penetration rate in the country soared.

We present the estimation results in Figure OA2, which illustrates the dynamic relationship between a city's average temperature in January and the monthly market share of EVs in the passenger vehicle market (Panel A) and across different price-tier submarkets (Panels B to D) at the city level. Panel A shows that temperature has a significant impact on the market share of EVs. After the breakthrough in EV technology in early 2020, there is a growing positive association between a city's average January temperature and its market share of EVs. On average, a one-degree Celsius increase in January temperature results in a 0.371 percentage point increase in the monthly market share of EVs after April 2020. This effect corresponds to an 18.8 percent increase from the average EV market share before April 2020 (0.0197) and is statistically significant at the one percent level. Another way to interpret the magnitude of this impact is by comparing the average January temperature between southern China (6.89 °C) and northern China (−8.50 °C), divided by the zero-degree isothermal line in January. The temperature gap of 15.39 degrees Celsius would lead to a difference of 5.7 percentage points in the market share of EVs. This pattern suggests that temperature is an important determinant of EV penetration and supports the use of average January temperature as the *share* component of the shift-share instrument.

Panels B to D of Figure OA2 show that the impact of January temperature on the market share of EVs is more pronounced in the low- and mid-end market segments. The differential impacts across price-tier submarkets hint at different market responses to the emergence of EVs in different market segments. Importantly, in all panels of Figure OA2, there is little or no pre-trend for the estimated impact of average January temperature on the market share of EVs before the breakthrough in EV technology in early 2020. The significant impact of temperature only started after early 2020. The pattern increases our confidence in the validity of our identification strategy, as any unobserved smooth economic trends would have difficulty explaining the sharp increase in EV penetration following the breakthrough in EV technology.

B. Conceptual model of EV penetration and high-end ICEV sales

We propose a simple conceptual model to explain why EV penetration may increase the sales of high-end ICEVs. We assume the willingness to pay (WTP) of income group i for car model c depends on two factors: 1) the functional value of the car, denoted as F_c, and 2) the social recognition of the car, denoted as S_c. Without loss of generality, we assume a linear functional form:

$$WTP_{ic} = \alpha_i F_c + \beta_i S_c,$$

where α_i and β_i are group-specific weights associated with the functional value and the social recognition of model c, and $\alpha_i + \beta_i = 1$. We also assume that β_i increases with income, i.e., higher-income consumers place a greater weight on the social recognition of a model.

The functional value (F_c) is entirely determined by a car model's physical attributes, such as size and horsepower. Thus, F_c is a fixed parameter. The social value (S_c) is influenced by two key factors: 1) model attributes associated with social recognition, such as brand and power type (i.e., EV or ICEV), and 2) the average expenditure necessary to acquire these attributes. The second factor can be considered as a form of peer effect, wherein the social value of an attribute rises with the average expenditure required to obtain it and the income levels of consumers who possess the attribute. Since physical attributes are time-invariant, changes in WTP for a car model are primarily driven by shifts in peer effects.

Following the technological advancements in early 2020, the manufacturing costs and prices of EVs significantly dropped. As a result, the average expenditure required to purchase an EV substantially reduced, leading to a surge in EV penetration after 2020, especially in the low-end market. Meanwhile, the prices of ICEVs remained relatively stable. As more consumers substituted low-end ICEVs with cheaper EVs, the average price gap between sold EVs and ICEVs increased. Figure OA3 illustrates that after 2020, this gap expanded, primarily due to the surge in low-end EV sales.[1] The average income difference between EV and ICEV owners is likely to increase as well.[2] This shift is likely to enhance the social value of ICEVs relative to EVs. Since consumers in the high-end segment place greater emphasis on the social value of cars, this factor is likely to drive more consumers in the high-end segment toward purchasing high-end ICEVs.

Moreover, for high-end ICEV brands, their relatively cheaper ICEV models are more likely to be substituted by EV brands. As a result, the average prices of sold cars from high-end ICEV brands are likely to increase, thereby boosting the social value of these high-end ICEV brands. This effect is also likely to attract more consumers who place greater importance on the social value of cars, driving them to purchase high-end ICEVs.

C. Preliminary evidence for the two mechanisms of the market size effect

We conduct two preliminary tests to provide evidence for the two mechanisms of the

[1] The average price of sold EVs is calculated as the retail prices of different EV models weighted by their respective sales volumes. An increase in the sales of cheaper EV models reduces the average price of sold EVs.

[2] As potential consumers of low-end ICEVs shifted to cheap EVs, the remaining ICEV buyers were more likely to be higher-income.

market size effect. First, as shown in Table OA2, we show that EV penetration has a larger impact on EV sales in the high-end market segment in provinces with a higher share of households whose total vehicle value exceeds 300 thousand yuan in 2020. This result supports the notion that the emergence of EVs enables wealthy consumers to expand their vehicle portfolio.

Second, in Table OA3, we explore the impact of EV penetration on automobile sales within the low-end market by further dividing the low-end market into three segments: vehicles priced below 50 thousand yuan, between 50 thousand and 100 thousand yuan, and between 100 thousand and 150 thousand yuan. We find that EV penetration leads to a greater increase in EV sales in lower-price segments within the low-end market. This pattern is consistent with the notion that the reduction in the minimum price threshold stimulates new demand from individuals previously constrained by budgets.

D. Results using two alternative proxies for brand value and customer recognition

We have provided evidence for the importance of brand social value by showing that only high-end ICEV brands with strong brand images and social recognition benefit from the emergence of EVs within the high-end market in Tables 4 and 5. Here, we corroborate the robustness of this finding using two alternative proxies for brand value and customer recognition in Tables OA6 and OA7.

First, in Table OA6, we study the impact of EV penetration on the market share of the top-selling ICEV brands. We define the top 1, top 2, and top 3 ICEV brands based on their market share ranking in their respective city and price-tier submarkets in 2019.[3] Note that the top-selling brands are specific to each city's market segments. For instance, the top-selling ICEV brand might be Mercedes-Benz in Shanghai, BMW in Kaifeng, and Audi in Changchun in the high-end market. This heterogeneity in consumer preferences can be attributed to various factors, such as cultural values and social norms, which vary significantly across different regions in China. This city-segment-specific ranking allows us to more precisely

[3] Using data in 2019, a period before the surge of EVs, to identify the top brands helps mitigate potential endogeneity concerns related to this variable.

identify the top brands associated with higher brand value and customer recognition in the local market. In Columns (1), (3), and (5) of Table OA6, as before, we define EV penetration as the cumulative share of EV sales until last month in a city's passenger vehicle market. In Columns (2), (4), and (6), for robustness checks, we define EV penetration as the cumulative share of EV sales until last month in the respective price-tier submarket of a city.

The results across all columns consistently show that EV penetration has a small positive impact on top ICEV brands' market share in the low-end market, a modest positive impact in the mid-end market, and the largest positive impact in the high-end market. For example, Column (1) suggests that when EV penetration increases by one percentage point, the market share of ICEV models for the top 1 brand increases by 0.21 percentage points in the low-end market, 0.96 percentage points in the mid-end market, and 2.29 percentage points in the high-end market, respectively. It confirms that, in the high-end market, ICEV models from top brands with high brand value and social prestige benefit the most from increased EV penetration.

Second, we use the quality reliability scores of automobile brands obtained from the *Consumer Reports* website as another proxy for social recognition. The website covers 29 popular high-end brands and we use the score from 2018 to mitigate endogeneity concerns. After merging with our data, we are left with 20 brands, accounting for approximately 94 percent of total sales in the high-end market.[4] Then, we examine whether the impact of EV penetration on a brand's market share changes with its quality reliability score. To do so, we regress a brand's market share on the interaction between EV penetration and the brand's quality reliability score in 2018. We use the interaction between the national cumulative EV penetration rate until last month, the city average temperature in January, and the quality reliability score in 2018 as the IV for 2SLS estimation.

The results are presented in Table OA7. Because *Consumer Reports* only covers the high-end brands, our analysis focuses on the high-end segment. Column (1) presents the

[4] The complete rankings of the 2018 Consumer Reports Automobile Reliability list are as follows (from top to bottom): Lexus, Toyota, Mazda, Subaru, KIA, Infiniti, Audi, BMW, MINI, Hyundai, Porsche, Genesis, Acura, Nissan, Honda, Volkswagen, Mercedes-Benz, Ford, Buick, Lincoln, Dodge, Jeep, Chevrolet, Chrysler, GMC, RAM, Tesla, Cadillac, and Volvo.

first-stage regression results. The F-statistic is much larger than 10, indicating a strong first-stage relationship between the IV and endogenous variable. Columns (2) and (3) suggest that brands associated with higher reliability scores witness an increase in both ICEV and EV market shares as EV penetration rises. However, the increase in ICEV market share is much higher than the increase in EV market share. The results confirm our previous finding that a brand's social prestige and customer recognition are vital in enhancing its ICEV models' market performance with the emergence of EVs.

E. Online Appendix Tables and Figures

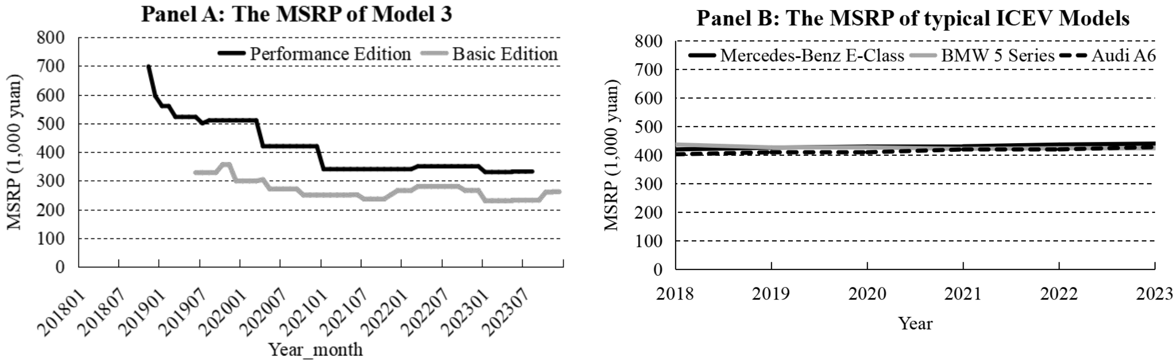

FIGURE OA1 The changes in the MSRP of typical EV and ICEV models

NOTES: This figure illustrates the changes in the MSRP of a typical EV model (Tesla Model 3 in Panel A) and three typical ICEV models (Mercedes-Benz E-Class, BMW 5 series, and Audi A6 in Panel B). The Performance Edition of the Tesla Model 3 was introduced in mainland China in November 2018 and was discontinued in September 2023. The Basic Edition was launched in June 2019. The MSRP of the Tesla Model 3 considers the EV subsidies provided by the Chinese government. The MSRPs of the ICEV models are based on their basic editions. Data sources: Tesla China's official website and Dongchedi website.

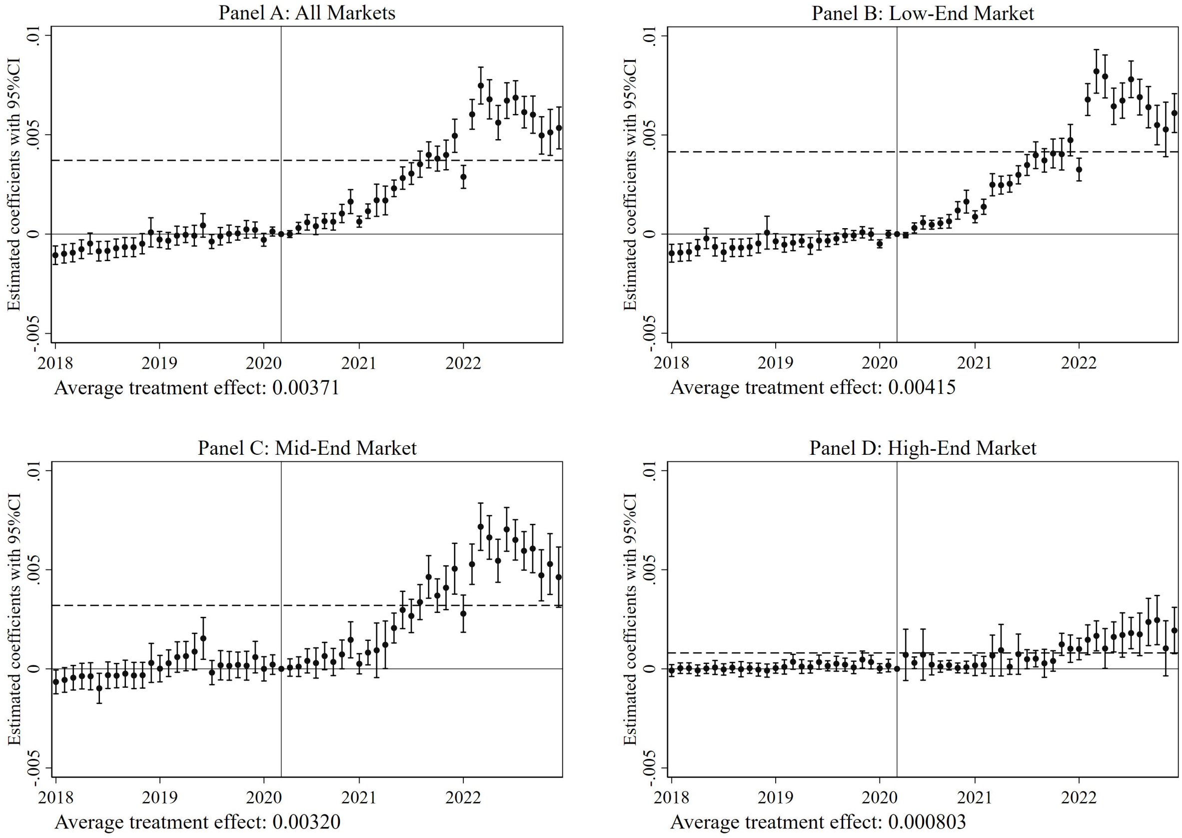

FIGURE OA2 January temperature and the monthly share of EV sales

NOTES: This figure illustrates the dynamic effects of a city's January temperature on the monthly market share of EVs across different price-tier submarkets. We use April 2020 as the benchmark period and all estimated impacts are relative to this period. The 95 percent confidence intervals are reported with the coefficient estimates. The specification includes all city-year-level control variables, as well as city fixed effects and year-month fixed effects. The dashed horizontal line represents the average effect of January temperature after April 2020.

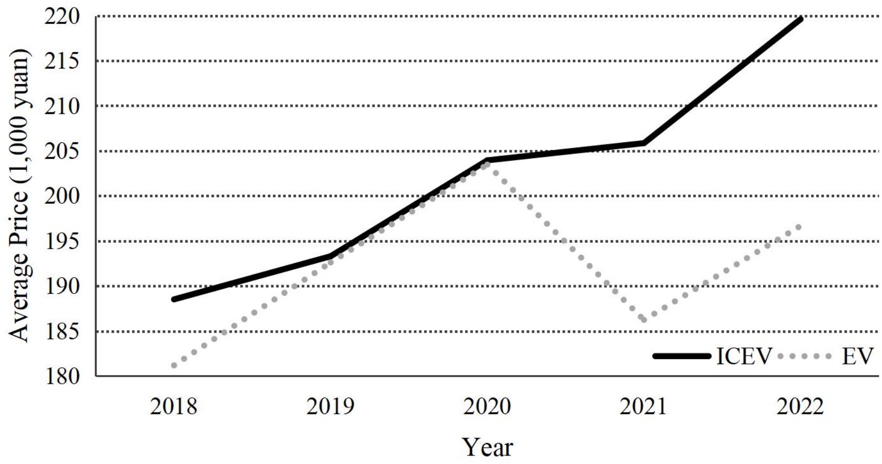

FIGURE OA3 Average prices of sold EVs and ICEVs

Note: This figure illustrates the trends in average prices of all sold EVs and ICEVs from 2018 to 2022. We use the MSRP as a proxy for retail prices. The rise in average EV prices from 2018 to 2020 can be attributed to the introduction of new models by BYD and Tesla. The decline in 2021 is primarily driven by the surge in sales of low-end EVs, such as the Wuling Hongguang Mini, which lowered the entry-level price for car ownership. The technological advancements in battery happened around early 2020.

TABLE OA1 Summary statistics

Panel A: By-submarket variables at the city-time(-brand) level

Variable name	**Low-end market**					**Mid-end market**					**High-end market**				
	Mean	S.D.	Min	Max	Obs	Mean	S.D.	Min	Max	Obs	Mean	S.D.	Min	Max	Obs
TotalSale	2,821	3,507	0	44,158	17,464	2,165	3,970	0	66,748	17,464	793	1,793	0	21,674	17,464
#ICEVSale	2,585	3,235	0	39,339	17,464	1,825	2,943	0	31,411	17,464	747	1,640	0	18,856	17,464
#EVSale	236	577	0	17,564	17,464	340	1,379	0	42,661	17,464	46	217	0	8,850	17,464
#MainstreamShare	0.801	0.072	0	1	17,419	0.755	0.107	0	1	17,412	0.774	0.136	0	1	17,362
*MainstreamShare_ICEV	0.765	0.097	0	1	17,419	0.744	0.115	0	1	17,412	0.764	0.135	0	1	17,362
*MainstreamShare_EV	0.035	0.057	0	0.623	17,419	0.011	0.020	0	0.752	17,412	0.010	0.019	0	1	17,362
#NicheShare	0.179	0.065	0	1	17,419	0.192	0.075	0	1	17,412	0.215	0.132	0	1	17,362
*NicheShare_ICEV	0.163	0.064	0	1	17,419	0.173	0.073	0	1	17,412	0.208	0.130	0	1	17,362
*NicheShare_EV	0.016	0.032	0	0.804	17,419	0.019	0.038	0	0.675	17,412	0.007	0.027	0	0.889	17,362
#EVsOnlyShare	0.020	0.035	0	0.598	17,419	0.052	0.080	0	1	17,412	0.011	0.034	0	1	17,362
EVmodel2018	0.074	0.183	0	1	77	0.261	0.361	0	1	70	0.093	0.237	0	1	36
BMShare	0.014	0.032	0	1	1,180,551	0.015	0.042	0	1	1,110,060	0.033	0.075	0	1	513,386

Panel B: Variables that do not differentiate between market segments

Variable name		Mean	S.D.	Min	Max	Obs
Market-level	EVShare_N	0.050	0.022	0	0.103	59
City-level	EVShare	0.028	0.035	0	0.299	17,444
	EVSharecur	0.073	0.097	0	0.713	17,431
	Temp (degrees Celsius)	1.331	9.0155	−24.873	19.321	296
	PubBus (per 1,000 residents)	0.332	0.291	0.009	2.973	1,480
	Roadpc (sq.m)	21.270	8.032	4.172	57.609	1,480
	WastewaterTR	0.952	0.075	0.235	1.323	1,480
	Pop (in million)	4.484	3.760	0.196	32.133	1,480
	GDPpc (yuan)	67,261	36,159	12,656	258,682	1,480

NOTES: *TotalSale* denotes the sales volume of all vehicles in a specific market segment within a given city-year-month, which equals the sum of sales of ICEVs (*ICEVSale*) and EVs (*EVSale*). By categorizing brand types, we define *MainstreamShare*, *NicheShare*, and *EVOnlyShare* as the market shares of mainstream brands, niche brands, and EVs-only brands, respectively. Mainstream and niche brands offer both ICEV and EV models, with *MainstreamShare_ICEV* (*NicheShare_ICEV*) and *MainstreamShare_EV* (*NicheShare_EV*) representing the proportions of sales for the two types of models. *EVModel2018* denotes the proportion of EV models among a brand's total vehicle models in 2018. *BMShare* denotes a brand's market share within its respective price-tier segment at the city-year-month level. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. *EVShare_N* refers to the cumulative EV penetration rate until last month in the passenger vehicle market for the whole country. *EVSharecur* denotes the share of EV sales in a city's passenger vehicle market for the current month. *Temp* denotes a city's average temperature in January. *PubBus*, *Roadpc*, *WastewaterTR*, *Pop*, and *GDPpc* are the number of public buses per 1,000 people, the road area per capita, the centralized sewage treatment rate, the residential population, and GDP per capita at the city-year level, respectively.

TABLE OA2 Household vehicle portfolios (IV)

	(1) Low-end	(2) Mid-end	(3) High-end
		ln(EVSale)	
EVShare × High	21.820	80.847	138.494**
	(94.849)	(87.590)	(64.200)
EVShare	22.335***	19.697***	12.844***
	(6.698)	(5.448)	(4.322)
N	17,444	17,444	17,444
D.V. Mean before April 2020	92.51	130.23	21.54
City-Year Level Controls	Y	Y	Y
City FEs	Y	Y	Y
Year-Month FEs	Y	Y	Y

NOTES: The dependent variable is the log of EV sales at the city-year-month level. *High* represents the provincial-level share of households whose total vehicle ownership is valued at over 300,000 yuan in 2020. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The coefficient of *EVShare*×*High* captures the differential effect of vehicle electrification between regions with higher and lower purchasing power. We employ two instrumental variables in the regressions: (i) the interaction between local average temperature in January and national cumulative EV penetration rate until last month (*Temp*×*EVShare_N*), and (ii) the interaction between local average temperature in January, national cumulative EV penetration rate until last month, and the provincial-level share of households whose total vehicle ownership is valued at over 300,000 yuan in 2020 (*Temp*×*EVShare_N*×*High*). The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020 before taking the log. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE OA3 The differential impact of EV penetration on low-end market (IV)

	(1) ln(TotalSale)	(2) ln(ICEVSale)	(3) ln(EVSale)
Panel A: Low-end market (MSRP < 50,000 yuan)			
EVShare	5.406***	-4.267***	32.745***
	(1.586)	(1.337)	(4.096)
N	17,444	17,444	17,444
D.V. Mean before April 2020	95.20	95.08	0.12
Panel B: Low-end market (50,000 yuan ≤ MSRP < 100,000 yuan)			
EVShare	6.440***	-2.611**	32.478***
	(1.137)	(1.032)	(4.547)
N	17,444	17,444	17,444
D.V. Mean before April 2020	1092.17	1044.64	47.52
Panel C: Low-end market (100,000 yuan ≤ MSRP < 150,000 yuan)			
EVShare	-0.527	-2.687**	25.980***
	(1.023)	(1.043)	(3.835)
N	17,444	17,444	17,444
D.V. Mean before April 2020	1874.63	1829.76	44.87
City-Year Level Controls	Y	Y	Y
City FEs	Y	Y	Y
Year-Month FEs	Y	Y	Y

NOTES: Panels A to C report the 2SLS estimation results of the impact of EV penetration on vehicle sales in different segments of the low-end market. The dependent variables in Columns 1 to 3 are total vehicle sales, ICEV sales, and EV sales, respectively. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020 before taking the log. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE OA4 The impact of EV penetration on automobile sales (OLS)

	(1) ln(TotalSale)	(2) ln(ICEVSale)	(3) ln(EVSale)
Panel A: Low-end market			
EVShare	2.271***	-0.641	3.092**
	(0.486)	(0.603)	(1.390)
N	17,444	17,444	17,444
D.V. Mean before April 2020	3062.00	2969.49	92.51
Panel B: Mid-end market			
EVShare	1.859***	-0.368	5.947***
	(0.527)	(0.477)	(1.285)
N	17,444	17,444	17,444
D.V. Mean before April 2020	1926.14	1795.91	130.23
Panel C: High-end market			
EVShare	1.248*	0.419	7.084***
	(0.683)	(0.717)	(1.196)
N	17,444	17,444	17,444
D.V. Mean before April 2020	778.35	756.81	21.54
City-Year Level Controls	Y	Y	Y
City FEs	Y	Y	Y
Year-Month FEs	Y	Y	Y

NOTES: This table reports the corresponding OLS regression results of the impact of EV penetration on vehicle sales for Panels C to E of Table 1. The dependent variables in Columns 1 to 3 are the natural logarithm of total vehicle sales, ICEV sales, and EV sales, respectively. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020 before taking the log. Standard errors clustered at the city level are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE OA5 The development of EV models for mainstream and niche brands

Market segment	Brand Type	Number of models (Proportion of EV models)				
		2018	2019	2020	2021	2022
Low-end	Mainstream	226 (0.07)	239 (0.11)	212 (0.13)	211 (0.14)	211 (0.16)
	Niche	347 (0.09)	323 (0.12)	270 (0.14)	221 (0.19)	188 (0.20)
Mid-end	Mainstream	104 (0.16)	115 (0.22)	121 (0.26)	151 (0.28)	158 (0.29)
	Niche	194 (0.32)	218 (0.38)	210 (0.41)	226 (0.45)	222 (0.49)
High-end	Mainstream	106 (0.10)	113 (0.12)	106 (0.14)	107 (0.16)	116 (0.22)
	Niche	96 (0.15)	96 (0.19)	84 (0.25)	89 (0.29)	92 (0.33)

NOTES: This table reports the total number of vehicle models and the proportion of EV models for mainstream and niche brands each year across price-tier market segments. The proportion of EV models among all vehicle models is displayed in parentheses.

TABLE OA6 EV penetration and market share of top ICEV brands

	(1) Top 1 Share	(2) Top 1 Share	(3) Top 2 Share	(4) Top 2 Share	(5) Top 3 Share	(6) Top 3 Share
Panel A: Low-end market						
EVShare	0.213	0.178	0.304	0.284	0.418	0.402
	(0.235)	(0.232)	(0.337)	(0.332)	(0.340)	(0.334)
N	17,418	17,418	17,418	17,418	17,418	17,418
D.V. Mean pre-April 2020	0.158	0.158	0.272	0.272	0.364	0.364
Panel B: Mid-end market						
EVShare	0.955***	0.973***	1.851***	1.875***	1.290***	1.303***
	(0.276)	(0.297)	(0.427)	(0.439)	(0.412)	(0.427)
N	17,410	17,410	17,410	17,410	17,410	17,410
D.V. Mean pre-April 2020	0.256	0.256	0.415	0.415	0.529	0.529
Panel C: High-end market						
EVShare	2.288***	13.338***	2.401***	14.106***	2.481***	14.593***
	(0.423)	(4.260)	(0.491)	(4.588)	(0.518)	(4.848)
N	17,354	17,354	17,354	17,354	17,354	17,354
D.V. Mean pre-April 2020	0.274	0.274	0.465	0.465	0.603	0.603
EVShare is defined based on:	Entire market	Sub-market	Entire market	Sub-market	Entire market	Sub-market
City-Year Level Controls	Y	Y	Y	Y	Y	Y
City FEs	Y	Y	Y	Y	Y	Y
Year-Month FEs	Y	Y	Y	Y	Y	Y

NOTES: This table examines the impact of EV penetration on the market share of top ICEV brands. The dependent variables represent the market shares of top ICEV brands in a city's ICEV segment. The top 1, top 2, and top 3 ICEV brands are defined based on their market share ranking in their respective city and price-tier segments in 2019. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market in Columns 1, 3, and 5, while it represents the cumulative share of EV sales until last month in the respective price-tier segment of a city in Columns 2, 4, and 6. The regressions control for city-year-level characteristics, city fixed effects, and year-month fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020. Standard errors clustered at the city level are reported in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

TABLE OA7 Brand reliability score, EV penetration and market share in high-end market

	(1) EVShare × QS2018	(2) ICEV_Bshare	(3) EV_Bshare
Temp × EVShare_N × QS2018	0.0313***		
	(0.00299)		
EVShare × QS2018		0.639***	0.0197***
		(0.150)	(0.00626)
N	294,234	294,234	294,234
Kleibergen-Paap F-stat.	109.02		
D.V. Mean pre-April 2020		0.0556	0.000256
City × Year-Month FEs	Y	Y	Y
City × Brand FEs	Y	Y	Y
Year-Month × Brand FEs	Y	Y	Y

NOTES: The dependent variables in columns 2 and 3 are the market share of a brand's ICEV models (*ICEV_Bshare*) and the market share of a brand's EV models (*EV_Bshare*) in the high-end submarket. Column (1) presents the first-stage regression results. Observations are at the year-month-city-brand level. *EVShare* denotes the cumulative share of EV sales until last month in a city's passenger vehicle market. The instrument (*Temp* × *EVShare_N* × *QS2018*) is the interaction between a city's average January temperature, national cumulative EV penetration rate until last month, and a brand's quality reliability score in 2018 (*QS2018*). The regressions control for city-year-level characteristics, city-year-month fixed effects, city-brand fixed effects, and year-month-brand fixed effects. For each regression, we also report the mean value of the dependent variable before April 2020. Standard errors clustered at the city level are reported in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.