Research on the Dynamic Game in Consumer Choice Between Fuel and Electric Vehicles

Junhao Wu[a]
Rugao International Academy, Nantong, Jiangsu, 226500, China

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Abstract: This study uses a coordinated game model to analyze consumer behavior in the transition between fuel and electric vehicles (EVs), emphasizing the synergistic role of government policy incentives, regional infrastructure equity, and collective social norms in shaping market equilibrium. A comparative case study of Norwegian EV dominance and Chinese subsidy-driven volatility shows that fragmented policies (e.g., sudden subsidy cuts or uneven infrastructure investment) cannot break the tram sector's dependence, while an integrated strategy achieves a stable Nash equilibrium. Key findings highlight the environmental and economic benefits of electric vehicles, including a 50% lifecycle reduction and long-term cost savings, but also highlight ongoing challenges: the urban-rural tram infrastructure rate gap (12% coverage), the unpredictability of post-subsidy market volatility (sales fell by 40% after subsidy cuts), and socio-geocultural resistance (e.g., fossil fuel dependence in Texas). To address these issues, the study proposes a multi-dimensional framework approach: phased subsidy cuts linked to market penetration thresholds centered on government decision-making, decentralized solar charging networks for rural areas centered on infrastructure, and behavior-based campaigns using social media and education based on popular social preferences. Theoretically, this paper integrates Debreu's dynamic equilibrium (analyzing subsidy phase-out thresholds) with Buchanan's coordination paradigm (for infrastructure-public preference alignment), providing a dual lens to optimize policy timing and stakeholder incentives.

1 INTRODUCTION

The global transition to electric vehicles (EVs) is a critical component of achieving carbon neutrality, yet consumer adoption remains influenced by cost, infrastructure, and cultural factors. As the world enters a phase of rapid technological development, the environmental hazards brought about by the process of industrial modernization have become a challenge for the entire globe. From the Paris Agreement to carbon neutrality, the shift from traditional fuels to electric and new energy sources has made environmental protection a global priority. Especially, Drive EV adoption is especially targeted by Global carbon neutrality. From the consumer's perspective, their choices are still influenced by cost differentials, infrastructure gaps, and cultural inertia. For instance, Norway's EV market share reached about eighty percent (82%) in 2023 through tax exemptions and charging networks, while Texas retained 93% fossil fuel vehicles due to infrastructure deficits and cultural resistance (IEA, 2023). These reflect the different preferences of consumers in various countries towards the oil and electric vehicle market. In order to better understand the government and society adjustments to the consumption market of electric vehicles to study its influences on the formation of Nash equilibrium and coordinated games, this study examines how policy coordination reshapes market equilibrium through a dynamic game framework.

External psychological effect: Smith & Jones (2021) identified a "bandwagon effect" where peer preferences accelerate EV adoption. This psychological effect of the trend toward popular choices is seen as an important basis for guiding consumers in their choices of electric vehicles. Consumers may more readily accept car types that are more popular with the public.

[a] https://orcid.org/0009-0000-3151-7166

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The guiding nature of government policy: Wang et al. (2022) demonstrated that subsidies exceeding $5,000 significantly increase EV adoption by lowering upfront costs. This example shows that the macro-control of government policies is a decisive factor that cannot be ignored for the competitiveness of the electric vehicle industry in the automotive consumer market. The low market price of electric vehicles after subsidies is a key reason for consumer choice.

Infrastructure Impact: Lee (2023) highlighted a strong correlation between charging density and urban EV penetration. The completeness of basic equipment is an important reason affecting consumers' choices of related products. This indicates that the local availability of corresponding basic supporting facilities, such as charging stations for electric vehicles, is an important factor for local consumers when choosing between petrol and electric cars. It is an explanation of the regional influence on the hybrid vehicle market.

Existing studies often isolate policy, infrastructure, or social factors, neglecting their synergistic impact on consumer behavior and market equilibrium. Most scholars' articles mainly study the impact factors of a specific aspect on consumers' choice judgments in the economic market. Such research tends to overlook the cumulative effects between different factors, resulting in conclusions that lack flexibility, limit usability, and fail to analyse the economy from both macro and micro perspectives. Fragmented interventions fail to address systemic path dependency. In reality, very few scholars analyse consumers' preferences for goods in the economic market using multi-angle, multi-faceted, and multi-factor research methods. As a result, objective choices cannot be well reflected in consumers due to the lack of relevant research analysis. As explained in 1.2, the influencing factors from the three different aspects of society, government, and infrastructure have not been unified and integrated into research, resulting in the current research on the market tendencies of oil and electric vehicles being overly singular and lacking comprehensiveness, making the analysis of the market insufficiently objective and complete (Wang, et al., 2022; Lee, 2023; Zhang & Ren, 2023).

In order to ensure the comprehensive availability of the research, during the course of this study, coordinated games will be regarded as the main approach to researching consumer choices regarding electric vehicles, thereby analysing the impact of government, society, and infrastructure on consumer choices through game theory concepts such as Nash equilibrium. During the research process, government variables such as subsidies and restrictions will interact with social preferences for a joint study. Additionally, actual data and conclusions from previous literature will be used to verify the authenticity of the results. The aim is to provide the public with a more reasonable and economically viable choice of electric vehicles through a relatively objective and multi-faceted research outcome. This study aims to provide a comprehensive understanding of consumer preferences for EVs through a multi-faceted analysis of government policies, social factors, and infrastructure impacts.

2 CASE DESCRIPTION

2.1 China's Subsidy-Driven Market Transition

China's phased subsidy policy initially boosted EV adoption but faced challenges when subsidies were reduced. To promote new energy industries, the Chinese government implemented a phased subsidy policy, such as the '10 cities, 1000 vehicles' plan, which initially boosted EV adoption in the public sector. However, the sudden reduction in subsidies after the industry reached initial maturity led to a 40% decline in EV sales. Since the reduction of subsidies for electric vehicles in 2019, the total sales of the new energy electric vehicle market have decreased by 40% compared to the past, which highlights the need for stable coordination of the government to be an important part of the vigorous development of the electric vehicle industry (Ma et al., 2017).

2.2 Policy, Infrastructure, and Social Preferences: A Comparative Analysis of EV Adoption in Norway and Texas

The contrasting cases of Norway and Texas illustrate how policy coordination, infrastructure development, and social preferences shape EV adoption outcomes. Norway, a Nordic country, will account for more than 80% of the electric vehicle market in 2023 with exemption from vehicle purchase tax, full subsidy for national tram charging fees, and high-density tram supporting systems, and has established an environmental protection strategy with tram transportation as the core of transportation (IEA, 2023, Lee, 2023). Through the Norwegian government's set of tram policy models, it is shown that the coordinated investment in policy and infrastructure has greatly accelerated the market coverage of trams for fuel vehicles (IEA, 2023). In contrast, The Texas state government's lax, non-rigid new energy vehicle promotion policy for electric car companies and the resistance to the local deep fuel vehicle culture has led to the fact that petroleum fuel still accounts for the majority of transportation, accounting for about 90% of the total number of vehicles, as shown in Table 1 (IEA, 2023; Alkhathlan & Javid, 2015).

Table 1: Tram differentiation in Norway and Texas

Dimension	Norway	Texas, USA
Policy coordination	Tax reductions, infrastructure investment, and social mobilisation are proceeding on three parallel tracks.	Federal subsidies are isolated, and local policies are lacking.
Infrastructure coverage	The density of charging stations is eight times that of Texas.	Less than 5% of charging piles in rural areas
Social preference	With a high degree of environmental recognition, EVs have become status symbols.	There is strong cultural resistance, and fuel vehicles are bound to the values of "freedom".
Market Results	EVs accounted for 82% of the total in 2023	Fuel vehicles accounted for 93%.

Revelation: The Norwegian case indicates the "triple synergy" of policy, infrastructure, and culture is the core mechanism for breaking path dependence. Conversely, the disjointed policies and lagging infrastructure in Texas have led the market to be locked into an inefficient equilibrium. The contrasting cases of Norway and Texas highlight the importance of coordinated policy, infrastructure, and social engagement in driving EV adoption.

3 ANALYSIS ON THE PROBLEM

3.1 Positive Impacts

3.1.1 Significant Environmental Benefits of Electric Vehicles

EVs provide significant environmental benefits through reduced emissions and improved air quality. EVs offer multi-faceted environmental benefits, including reduced CO2 emissions, improved air quality, and ecosystem optimization.

Life cycle emission reduction of lithium battery raw materials: While the production of lithium-ion batteries, the main fuel for electric vehicles, produces 5-10 tonnes of CO2, tram factories that are driven by green energy production (such as Tesla's Berlin Gigafactory) can reduce carbon pollution emissions by 40% by optimizing battery production (IPCC, 2022). In China, grid decarbonization policies (36% of non-fossil energy by 2023) have resulted in a 60% reduction in polluting gas emissions per kilometer from electric vehicles compared to fuel-powered vehicles (Yuan et al., 2015).

Local Pollution Control for Electric Vehicles: According to the study, PM2.5 concentrations in Beijing decreased from 80.6 μg/m³ (2015) to 38 μg/m³ (2023), with a 12% reduction in the proportion related to transportation gas emissions (Zhang & Ren, 2023).

Ecological synergy of new energy use: With an annual capacity of 150 kWh/m², the solar-integrated charging station in Oslo balances basic energy production with the protection of the ecological environment of the land (IEA, 2023).

3.1.2 High Economic Efficiency Brought by the Tram Industry

The advantages of the low cost of long-term tram production and the spillover effect of tram industrial production of electric vehicles have demonstrated economic viability through consumer purchases, savings, and macroeconomic transformation of the automotive industry.

Consumer Cost Analysis: China's EV ownership costs (purchase + electricity + maintenance) total 18,000 over 10 years, 2218,000 over 10 years, 2223,000) (Ma et al., 2017).

Industrial Upgrading: Battery energy density doubled from 150 Wh/kg (2015) to 300 Wh/kg (2023), driving advancements in energy storage and drones (Yang, 2024).

Employment and Trade: China's electric vehicle industry employs 1.5 million workers, and 60% of that human resources are used in battery manufacturing (Zhang & Ren, 2023). In 2023, China's total overseas exports of electric vehicles will reach 1.2 million units, and China has reduced its dependence on oil imports through the development of new energy fuels and the export of electric vehicles (Yang, 2024).

3.2 Existing Challenges

The challenges in EV adoption stem from infrastructure inequities, policy fluctuations, and socio-cultural resistance.

3.2.1 Inequities in Infrastructure: Spatial Distance Differences and Behavioral Habit Disorders

Infrastructure inequities between urban and rural areas deepen regional disparities in EV adoption. Large disparities in social, urban, and rural infrastructure exacerbate regional inequality in EV use. For example, Norway's high-density charging network (8 stations per 100 km) contrasts sharply with Texas's sparse coverage (less than 5% in rural areas), reflecting the impact of coordinated policy and investment on EV adoption (IEA, 2023; Alkhathlan & Javid, 2015). Charging Density: The same urban tram chargers contain only one in ten (12%) in rural areas (Lee, 2023). In China, this gap in coverage of urban and rural tram infrastructure coincides with the 2.5:1 urban-rural income gap, so the regional differences in tram infrastructure construction deepen the commodity stratification of consumer groups.

Behavioral Inertia: Research shows that the adoption rate of electric vehicles in Texas, USA, is very low (7%), and this phenomenon of indifference towards electric cars actually stems from the cultural resistance to them in Texas, where fuel cars symbolize "freedom" in the local culture (Alkhathlan & Javid, 2015)

3.2.2 Government Policy Fluctuations: Volatile Consumer Market Environment and Uncertainty About Popular Goods

Abrupt changes or enacted changes in government policies can undermine consumers' propensity to buy and businesses' earnings expectations.

Subsidy Rollback Effects: The Chinese government's 2022 reduction in subsidies for domestic EVs led to a 40% decline in consumer demand, highlighting the direct impact of policy changes on purchasing decisions. This volatility underscores the EV market's dependence on government support (Zhang & Ren, 2023).

Regulatory Fragmentation: Local governments in Texas lack a standardized set of industrial fees for the NEV industry, resulting in duplicate investment in their domestic tram companies (IEA, 2023).

3.2.3 Socio-Cultural Lock-In: Identity Politics and Path Dependency

Cultural narratives and institutional inertia hinder transitions.

Symbolic Resistance (Subsidy repatriation effect): In Texas, about seven in ten consumers (68%) associate gasoline vehicles with their regional identity (Texas residency) and resist the adoption of electric vehicles with a regional fuel culture (Alkhathlan & Javid, 2015)

Corporate Reluctance: Legacy automakers delay EV R&D due to sunk costs in combustion engine supply chains (Yang, 2024).

3.3 Extended Analysis: Dynamic Game Perspective

3.3.1 Coordination Failure in Multi-Stakeholder Systems

The absence of coordination among policymakers, firms, and consumers leads to a suboptimal market equilibrium.

Case: China's Subsidy Rollback: The abrupt shift in policy shifts has disrupted commodity supply chains, just as battery makers faced a huge $2 billion in stranded assets in response to a policy change in 2019 (Zhang & Ren, 2023).

Theoretical Framework: Using Debreu's dynamic equilibrium model, EV market stability requires Ui(EV)=αPj(EV)+β(Si−Ci)Ui(EV)=αPj(EV)+β(Si−Ci), where PjPj (peer adoption) and SiSi (policy benefits) must align (Liu, 2006).

3.3.2 Technical-Level Upper Limit Lock-In and Innovation-Level Breakthrough Dilemma

Due to the information network, externalities of high-paying technology positioning, and new energy electric vehicles, the traditional technology of automobile manufacturing occupies a dominant position in the whole production.

Battery Standardization: Competing standards (e.g., Tesla NACS vs. CCS) fragment the EV charging network, increasing the long-term cost of energy consumption by 15% for EV users (Lee, 2023).

Innovation Trade-offs: Hybrid electric vehicles (HEVs), a power-driven vehicle type that optimizes auxiliary fuel energy with electric energy, offer a transitional advantage for electric substitution of automotive fuels, but the existence of these hybrid electric vehicles will extend the actual time to reach the full electrification of automotive goods. In the United States, government commodity subsidies for HEVs crowd out production investment in EV development (IEA, 2023).

4 SUGGESTIONS

4.1 Policy Stability Through Gradual Subsidy Reform

4.1.1 Dynamic Subsidy Adjustment: Aligning Policy with Market Penetration

By learning from the Chinese government's post-2019 subsidy cuts for electric vehicles, the electric vehicle market has experienced a period of cooling in both production innovation and consumer intentions. This is in contrast to the fact that the Norwegian government's incremental tax exemption adjustments for electric vehicle consumers (e.g., a 5% reduction per year) have maintained confidence in the purchase of electric vehicles among mass consumers (IEA, 2023).

Adjustment based on market thresholds: Subsidy levels should be tied to EV market penetration (e.g., reducing subsidies by 30% when EV share exceeds 10%), preventing market oversaturation (Yang, 2024).

Differentiated regulation of regional conditions: Priority should be given to providing subsidies for tram consumption and production in underdeveloped regions (e.g., rural China in remote areas), and at the same time, incentives for production and consumption in urban markets saturated with tram consumption should be phased out for a certain period of time (Yang, 2024).

4.1.2 Transitioning from Purchase Subsidies to R&D Incentives

China's "subsidy-for-innovation" model redirected \$2.8 billion to battery R&D from 2020–2023, boosting energy density by 25% (Yang, 2024).

Policy Tools: Production Tax Credit for Tram Patents: The U.S. government provides a 15% corporate tax deduction to companies with EV-related patents, such as Tesla's 4680 battery technology (Yuan et al., 2015).

Public-Private R&D Funds: Norway's \$500 million Green Innovation Fund co-financed solid-state battery projects with private firms (IEA, 2023).

4.2 Equity in Tram Infrastructure: Bridging Geographical Space and Social Class Gaps

There are 0.3 chargers per square kilometer in rural China, compared to 2.1 in urban areas (Lee, 2023). Solutions include:

A new mode of charging for electric vehicles with distributed solar: Villages with low rainfall have deployed off-grid solar power stations to reduce the dependence of electric vehicle charging on the traditional grid (Zhang & Ren, 2023). For example, India's solar microgrids in rural Maharashtra reduced EV charging costs by 60% through daytime solar storage, offering a replicable model for low-rainfall regions.

Cross-Subsidy Mechanisms: Allocate 30% of urban EV tax revenue to rural infrastructure, as practiced in Germany's Ladeinfrastrukturprogramm (Lee, 2023).

Competing charging standards (e.g., CCS vs. NACS) raise user costs by 18% (Lee, 2023). Unified Protocols: Mandate ISO 15118-20 compliance for all new installations, enabling "plug-and-charge" interoperability (Lee, 2023). Data Transparency Platforms: Launch national charging maps (e.g., Norway's Elbilforeningen) to optimize station utilization (IEA, 2023).

4.3 Behavioral Interventions in Government: Using Social Dynamics

4.3.1 Leveraging Social Influence Mechanisms for EV Adoption

Norway's EV owners' Facebook groups increased peer influence efficacy by 40%, accelerating adoption (Smith & Jones, 2021).

Partnerships with well-known artists: Partnering with environmentally conscious celebrities, such as Eileen Gu, a famous Chinese skier, to promote the electric vehicle industry through its vast social appeal by using electric vehicles as a status symbol (Yang, 2024).

Gamified Policy Tools: China's 'Green Miles' app rewards users with tax rebates (up to 5% of annual vehicle tax) for sharing EV charging reviews, achieving 1.2 million user engagements in 2023 (Smith & Jones, 2021).

4.3.2 Education vs. Fossil Fuel Culture: Curriculum-Based Interventions

Texas's fossil fuel culture stems from its historical dominance of regional oil supply. Mitigation Strategies:

Government integration of electric vehicle policy into school curricula: Norway's STEM program has added an enrichment curriculum on EV-related technologies to 80% of Norwegian school curricula, shaping a positive perception of electric vehicle technology research among young people (IEA, 2023).

Community Tram Culture Workshop: Hold similar electric vehicle test drive events in areas with high environmental awareness that resist the development of gasoline vehicles and subtly cultivate environmental awareness of public trams, just like the Eco Mobility Festival in Japan (Yuan et al., 2015).

4.4 Multi-Field Technology Collaboration: Cross-Industry Cooperation in Tram Development

Only 5% of lithium-ion batteries are recycled globally.

Extended Producer Responsibility (EPR): According to the legal and regulatory requirements of the European Union for battery manufacturing, car manufacturers are required to recycle 95% of battery materials, and the mandatory constraints of the law are used to raise the awareness of social responsibility of electric car producers so that battery safety is basically guaranteed (Yang, 2024).

Blockchain traceability: The use of a distributed ledger to track the life cycle of a battery makes the number of ledgers public, greatly avoiding financial fraud and reducing illegal dumping (Zhang & Ren, 2023). CATL's blockchain platform tracks 100% of battery raw materials, reducing illegal dumping incidents by 75% in pilot provinces (Yang, 2024).

EVs can stabilize grids via vehicle-to-grid (V2G) systems, yet adoption remains below 1% (Yuan et al., 2015). Dynamic Pricing Incentives: Offer a 50% discount on electricity for V2G participants during peak hours (Yuan et al., 2015). Grid Upgrade Subsidies: China's State Grid allocated $1.2 billion to V2G-compatible transformer upgrades in 2023 (Yang, 2024).

5 CONCLUSION

The paper's research shows that the transition to electric vehicles (EVs) in the transportation market is not just a technological innovation or economic challenge but a complex game of coordination. Nash equilibrium in EV markets emerges only when government policies, infrastructure equity, and social preferences align.

Policy-infrastructure interdependence: The success of tram penetration in Norway stems from the Norwegian government's policy tax exemption subsidies and Norway's dense infrastructure charging network system, while the volatility of government tram subsidies in China highlights the hidden risks of policy intervention in the decentralized tram industry.

Dynamic influence of social and regional culture: Regional cultural accumulation, such as the dominant identity of fossil fuels in Texas or the green spirit of Nordic Norway, is either an obstacle to the development of electric cars or an accelerator of electric variation and this dynamic cultural attribute plays a role in reshaping consumer perceptions and social preferences in the coordination game.

The research provides actionable strategies for governments and industries: Dynamic Policy Calibration: Gradual subsidy reductions paired with R&D incentives can stabilize markets, as evidenced by China's battery innovation surge. Infrastructure Justice: Solar-powered rural charging stations and cross-regional subsidies can mitigate spatial disparities. Behavioral Leverage: Social media campaigns and educational programs, like Norway's STEM curricula, amplify peer effects and dismantle cultural resistance.

While this study offers systemic insights, two constraints warrant attention: Data scope: The reliance on secondary data limits the analysis of behavior at the micro level of coordinated games. Future research can integrate original surveys to capture consumers' nuanced decisions. Technological developments: The rapid development of solid-state batteries and V2G systems is likely to redefine the equilibrium in the electric vehicle market. It is essential to keep track of these technological innovations on a continuous basis. Forward-looking comprehensive outlook: The transition to electric vehicles is a typical microcosm of the broader challenges of sustainable industrial transformation. As the classical theory of dynamic equilibrium postulates, stability does not come from isolated interventions but from the continuous alignment of rules, resources, and social values. Policymakers must embrace this complexity if they move from "locked-in" fossil fuel inertia to a resilient low-carbon balance of electricity and new energy.

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