From Trade War to Green Transition: Optimal Electric Vehicle Tariffs with Revenue-Funded Subsidies*

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Abstract

Although electric vehicle (EV) adoption has accelerated in many parts of the world, the EV market in the US has fallen from a global leader to a laggard. China on the other hand has emerged as the dominant force in both EV adoption and production. How can the US advance its energy transition by leveraging low-cost, high-quality EVs from China while also protecting its domestic auto industry? We study a policy package that would allow Chinese EVs to enter the US market subject to tariffs, with the resulting tariff revenue recycled as subsidies for domestically produced EVs. We first develop a stylized theoretical model to illustrate the key forces such as the demand curvature, product substitution, and market power that shape the optimal tariff. Our empirical analysis is based on a flexible model of automobile market equilibrium estimated with detailed global vehicle sales data. The counterfactual simulations show that this policy package can substantially promote EV adoption and increase social welfare while balancing competing policy objectives. If the top 10 Chinese EV models were allowed to enter the US market, the optimal tariff would be about 25%, generating enough revenue to subsidize domestically produced EVs by nearly $7,500 per vehicle. Under this policy, the EV market share would more than double, and social welfare would rise by more than $45 billion annually.

Keywords: Electric vehicles, tariffs, subsidies, energy transition

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1 Introduction

The global transition in passenger transportation from internal combustion engine (ICE) vehicles to electric vehicles (EVs) represents perhaps the most profound change in the sector over the past century. Since their introduction to the mass market in 2011, EV sales reached 20.7 million units, accounting for nearly one-quarter of new vehicle sales globally by 2025.[1] However, penetration rates vary widely across regions: EVs accounted for 97% of new vehicle sales in Norway, 69% in Denmark, 54% in China, 29% in Germany, but only 9% in the US. The most notable development of this market is that the US has fallen from a market leader to a laggard over the past decade, while China has emerged as a dominant player in both EV production and adoption. The gap between the two countries has continued to widen in recent years: in 2025, EV sales in the US totaled 1.5 million units, down 4% from 2024, whereas EV sales in China reached 13 million units, up 17% from 2024.

How can the US effectively advance its energy transition in this sector while safeguarding the domestic manufacturing sector? In this study, we propose and examine a policy package that deviates from the current practice of effectively banning Chinese EV imports to the US[2] Specifically, the policy package permits low-cost, high-quality EVs from China to enter the US market subject to tariffs, with the resulting tariff revenue recycled into consumer subsidies for domestically produced EVs. The first prong of this package, allowing Chinese EV imports under tariff, resembles the approach adopted by the European Union (EU), which imposes vehicle cybersecurity requirements on all manufacturers, rather than only Chinese firms, while also levying tariffs on Chinese EVs.[3] The second prong of the policy recycles tariff revenue into subsidies for domestically produced EVs, thereby stimulating EV demand, supporting the domestic auto industry, and enhancing the policy's political feasibility.

Our analysis begins with a stylized theoretical model with simulations in which domestic automakers compete with imported EVs in a differentiated-product oligopoly. The social planner chooses the tariff on imported EVs and the subsidy for domestically produced EVs to maximize domestic social welfare, defined as the sum of consumer surplus, domestic firm profits, environ-

[1] EVs include battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

[2] The current US policies largely preclude Chinese EV imports to the US The Biden administration raised Section 301 tariffs on Chinese EVs to 100% in 2024, and the Commerce Department's connected-vehicle rule separately prohibits certain transactions involving connected-vehicle software and hardware tied to China, further limiting the commercial feasibility of Chinese EV sales in the US.

[3] The EU requires vehicle manufacturers to meet the United Nations Economic Commission for Europe (UNECE) UN R155 cybersecurity requirements, rather than China-specific connected-vehicle restrictions. Recently, Canada has reached an agreement with China to reduce the tariff on Chinese EVs from 100% to 6.1% for the first 49,000 units of imported EVs, and the cap will increase over time, thus paving the way for Chinese EVs to enter North America.

mental externalities, and government revenue. The effects of these policy instruments on each welfare component depend critically on demand curvature, the substitutability between imports and domestic products, and the relative number of domestic and imported EV models. When profit shifting from imports to domestic EVs and tariff revenue dominate consumer welfare losses, the optimal tariff is positive. Optimal tariffs are higher when domestic EV markups are high, imports and domestic EVs are close substitutes, tariff passthrough is low, and imported models are few relative to domestic models. Optimal subsidies are higher when domestic markups are high, and demand for domestic EVs is more elastic. Finally, environmental externalities associated with domestic and imported EVs shift the optimal levels of tariffs and subsidies in a manner analogous to Pigouvian taxation. Under a revenue-neutral tariff and subsidy package, the optimal tariff can be either higher or lower than the unconstrained policy choices, depending on the shadow value of the budget constraint. Interestingly, tariffs and subsidies could be either substitutes or complements depending on the strength of the cross-instrument price spillovers.

Informed by the theoretical and simulation results, we estimate an equilibrium model of the vehicle market with a flexible demand specification that captures substitution patterns across products and demand curvature (Berry, Levinsohn, and Pakes, 1995). The estimation is based on comprehensive data on vehicle sales and attributes from 13 countries over the 2004–2023 period; together, these countries accounted for 85% of global ICE sales and 95% of EV sales during the sample period. We supplement the aggregate data with household survey data, which enables us to construct micro-moments. The estimates reveal a strong preference for local brands, with particularly pronounced heterogeneity in such preferences in the US, implying strong within-brand substitution. More importantly, we find substantial heterogeneity in preferences over multiple vehicle attributes, which generates richer substitution patterns across products and more convex demand curves. Consistent with Miravete, Seim, and Thurk (2023) and Goldberg and Hellerstein (2013), this flexible demand estimation that exhibits rich preference heterogeneity for product attributes is crucial for understanding the passthrough of tariffs and subsidies, and therefore for determining the optimal policy design.

With the model premise estimated, we conduct counterfactual policy analysis where a certain number of Chinese EV models, e.g., top-10 or top-20 most popular EV models, is allowed to enter the US market under different policy scenarios: (1) tariffs on Chinese EV imports; (2) subsidies on domestic EVs; (3) a combination of tariffs and subsidies; and (4) adding revenue-neutral constraints to the policy combination. Our counterfactual analysis generates the following key findings. First, the introduction of low-cost, high-quality Chinese EVs into the US market creates a fundamental trade-off between environmental goals and domestic industrial protection. While

allowing entry significantly accelerates fleet electrification and benefits consumers through lower prices, it simultaneously harms domestic manufacturers by eroding their market share. Our counterfactual simulations show that total social welfare is "hump-shaped" with respect to the tariff rate, meaning that while some protection is welfare-improving, excessively high tariffs eventually become counterproductive. This hump-shaped relationship implies the existence of a strictly positive optimal tariff, ranging from 25% without revenue recycling to 27.5% with it. This specific rate best balances the extraction of rents from foreign firms against the consumer surplus losses caused by high import prices.

Second, the proposed policy of recycling tariff revenue into domestic EV subsidies shifts the welfare frontier upward, outperforming trade-only or subsidy-only approaches. This mechanism allows the government to maintain a less aggressive optimal tariff—calculated at approximately 25% while providing substantial consumer incentives of nearly $7,500 per domestic vehicle. Consequently, this package more than doubles the EV market share and generates over $45 billion in annual social welfare gains by balancing electrification with industrial stability.

Third, a critical driver of these welfare gains is the asymmetric pass-through of policies across different manufacturers. Chinese entrants, targeting price-sensitive middle-income consumers, tend to absorb a portion of the tariff burden through lower markups rather than passing the full cost to buyers. In contrast, domestic subsidies are highly effective at pushing the equilibrium toward the mass market, effectively lowering prices for consumers while bolstering the competitive position of domestic firms.

Finally, the optimal policy design and resulting welfare outcomes are sensitive to the number of imported models allowed to enter. As the variety of Chinese EV models increases, the associated consumer surplus losses from high tariffs are amplified, typically leading to a decrease in the optimal welfare-maximizing tariff rate. Our analysis shows that while adding more Chinese EV models enhances overall social welfare and adoption rates, it also necessitates a more calibrated revenue-recycling strategy to prevent excessive profit erosion for domestic incumbents.

Our study is related to several strands of literature. First, we contribute to the growing literature on the adoption of EVs (Li et al., 2017; Li, 2023; Springel, 2021; Muehlegger and Rapson, 2022). This literature shows that EV adoption is shaped by strong indirect network effects between charging infrastructure and vehicle demand, and that consumer subsidies can meaningfully increase EV uptake, although their effects depend on market structure, product availability, and policy design. More recent work also emphasizes that firms respond strategically to EV policies through pricing, product offerings, and other supply-side adjustments, implying that the welfare effects of subsidies extend beyond their direct impact on consumer demand (Kiso, 2022; Barwick,

Kwon, and Li, 2024; Kwon, 2025; Remmy, 2025; Wang and Xing, 2025). Our analysis adds to this literature by examining how a joint design of trade and industrial policy can affect EV diffusion in a global market. In doing so, it highlights how substitution patterns, pass-through, and market power mediate the effects of tariffs and domestic EV subsidies on market outcomes and welfare.

Second, our paper is related to the literature on the role of industrial policies, particularly in the context of EVs and other energy technologies (Gerarden, 2023; Bollinger et al., 2024; Banares-Sanchez et al., 2025; Barwick et al., 2025; Sabal, 2025; Allcott et al., 2026; Head et al., 2026). This literature shows that industrial policies can accelerate innovation, reshape supply chains, and influence production locations, but may also create important tradeoffs involving market power, fiscal costs, and international spillovers. Recent work on EVs and batteries further highlights the importance of learning-by-doing, domestic content requirements, and multi-stage supply-chain linkages in determining who captures the gains from clean industrial policy. Our paper differs from this literature by characterizing the optimal policy mix in the specific context of Chinese EV imports into the US market. More broadly, it connects trade policy, industrial policy, and environmental objectives within a unified quantitative framework that allows these interactions to be evaluated jointly.

Third, this study contributes to the analysis of trade policies under imperfect competition. While the foundational strategic trade literature established that governments could shift rents or improve welfare through export subsidies and tariffs (Spencer and Brander, 1983; Dixit, 1984; Brander and Spencer, 1985), early critiques highlighted that these results were highly sensitive to assumptions regarding market structure and retaliation (Eaton and Grossman, 1986; Bagwell and Staiger, 2002). More recent empirical work has moved toward quantitative structural models to discipline these theoretical ambiguities, evaluating how modern trade barriers interact with global value chains, sectoral linkages, and domestic industrial goals (Caliendo and Parro, 2015; Antràs and Chor, 2022; Baqaee and Farhi, 2024; Castro-Vincenzi et al., 2024). Our paper contributes to this evolving literature by empirically estimating a flexible differentiated-product equilibrium model of the global automobile market, in which demand curvature, substitution patterns, and pass-through are disciplined by comprehensive data. It also introduces a new policy package, recycling tariff revenue into subsidies for domestically produced EVs, and evaluates that joint policy in a setting where trade policy, industrial policy, and environmental objectives interact.

Our paper is perhaps most similar in spirit to Berry, Levinsohn, and Pakes (1999) which used the differentiated-product oligopoly framework to evaluate the impacts of an early strategic trade policy, namely voluntary export restraints (VER) on Japanese vehicle exports to the US in the

1980s.[4] While Berry, Levinsohn, and Pakes (1999) quantified the welfare losses associated with quantity-based trade restrictions, we examine a modern policy package of ad valorem tariffs coupled with revenue-funded subsidies. We demonstrate that this integrated approach can generate significant welfare gains for the US while simultaneously accelerating the domestic energy transition.

The remainder of this paper is organized as follows. Section 2 develops the theoretical model and provides Monte Carlo simulations to build intuition. Sections 3 and 4 describe the data and implement the empirical estimation. Section 5 conducts counterfactual simulations to provide a comprehensive evaluation of the market and welfare impacts of optimal policies upon introducing the top 10 Chinese EV models into the US market. Section 6 uncovers the underlying mechanisms of our proposed policy tools, focusing on the role of firm pass-through. Section 7 concludes.

2 Theoretical Model

Consider $j = 1, ..., J$ heterogeneous products with marginal cost C_j and demand $Q_j(\tilde{P}_1 - B_1(x_1), ..., \tilde{P}_J - B_J(x_J))$, where $B(x)$ is an additively separable non-price portion of utility. Prices $\tilde{P}_j$ adjust for tariffs on imports with $\tilde{P}_j = (1+\tau)P_j$ for $j \in J_f$. The marginal costs of domestic products are subsidized with $\sigma_j = \sigma$ such that $\tilde{c}_j = c_j - \sigma_j$ for $j \in J_d$. Given the policies (τ, σ), firms solve the following profit maximization problem:

$$\max_{P_j} (P_j - C_j + \sigma_j) Q_j(\tilde{P} - B(x))$$

$$[P_j]: \qquad F_j = \frac{P_j - C_j + \sigma_j}{P_j} - \frac{1}{\varepsilon_j^P(\tilde{P} - B(x))} = 0, \qquad \forall j = 1, ..., J, \tag{1}$$

where ε_j^P is the own-price elasticity of demand for product j. Stacking the first-order conditions F_j from Equation (1) into a vector $\mathbf{F}$, the Implicit Function Theorem implies passthrough of tariffs and subsidies:

$$\frac{\partial \tilde{\mathbf{P}}}{\partial \gamma} = -\left(\frac{\partial \mathbf{F}}{\partial \mathbf{P}}\right)^{-1} \frac{\partial \mathbf{F}}{\partial \gamma}, \tag{2}$$

for policies $\gamma = [\tau, \sigma]$. Firms pass through tariffs and subsidies to final consumer prices. The passthrough matrix depends on conduct through $\frac{\partial \mathbf{F}}{\partial \mathbf{P}}$ and on the curvature of demand through the Jacobian terms.

[4] There is a striking historical parallel between the 1980s VERs on Japanese cars and today's prohibitive tariffs on Chinese EVs; in both eras, the US government leveraged trade barriers to protect the same domestic incumbents from a foreign challenger.

The social planner maximizes the sum of consumer surplus, domestic producer surplus, the government budget balance, and externalities:

$$W(\tau,\sigma) = \underbrace{\sum_{j\in J}\int_0^{Q_j(\tilde{P})}(B_j(x_j)+Q_j^{-1}(s,\tilde{P}_{-j})-\tilde{P}_j)ds}_{\text{Consumer surplus}} + \underbrace{\sum_{j\in J_d}(P_j-C_j)Q_j(\tilde{P})}_{\text{Domestic profits}} + \underbrace{\sum_{j\in J}\phi e(x_j)Q_j(\tilde{P})}_{\text{Externalities}} + \underbrace{\sum_{j\in J_f}\tau P_j Q_j(\tilde{P}) - \sum_{j\in J_d}\sigma Q_j(\tilde{P})}_{\text{Government revenue net of expenditures}}, \tag{3}$$

where ϕ_j measure externalities induced by good j. The social planner chooses policies $\gamma = (\tau,\sigma)$ to maximize this objective function.

2.1 Optimal Policy Designs

Fixed Tariffs and Subsidies In the first set of analyses, we do not impose an explicit government budget balance constraint. The social planner sets policies freely. Taking the first-order conditions of Equation (3), we find:

$$\begin{aligned}
\frac{dW}{d\gamma} = &-\sum_{j\in J}\left[\frac{\partial\tilde{P}_j}{\partial\gamma}Q_j\right] && \text{(Consumer surplus)}\\
&+\sum_{j\in J_d}\left[(P_j-C_j)\sum_{k\in J}\frac{\partial Q_j}{\partial\tilde{P}_k}\frac{\partial\tilde{P}_k}{\partial\gamma}+\frac{\partial P_j}{\partial\gamma}Q_j\right] && \text{(Domestic profits)}\\
&+\sum_{j\in J}\phi e(x_j)\sum_{k\in J}\frac{\partial Q_j}{\partial\tilde{P}_k}\frac{\partial\tilde{P}_k}{\partial\gamma} && \text{(Externalities)}\\
&+\sum_{j\in J_f}\frac{d}{d\gamma}\left[\tau P_j Q_j\right]-\sum_{j\in J_d}\frac{d}{d\gamma}\left[\sigma Q_j\right]. && \text{(Government revenue)}
\end{aligned}$$

The primary pieces of the first-order conditions are:

1. *Changes in consumer surplus*: Consumer surplus loss (gains) due to passthrough of tariffs (subsidies). Passthrough behavior may be incomplete or more than complete, depending on the curvature of demand.

2. *Changes in domestic profits*: Domestic firms gain through the direct channel of diversion from imports to domestic products, holding prices fixed, and through the indirect channel of passthrough of rival tariffs.

3. *Changes in externalities*: The impact on externalities may be positive or negative, depending on the quantity distortions and the relative sizes of externalities for each product.

4. *Fiscal effects*: The social planner gains revenue from tariffs, accounting for diversion away from imports, and loses from subsidy expenditures.

Importantly, prices P and $\frac{dQ}{d\gamma}$ account for passthrough behavior of firms determined in Equation (2). In passthrough, we have $\frac{dP}{d\tau} \gtrless 0$ and $\frac{dP}{d\sigma} < 0$. The optimal policies are determined jointly by three forces. First, firms set prices as strategic complements, meaning a tariff on imports raises import prices and triggers domestic price increases. Strategic complementarity can be either enhanced or attenuated by the degree of product and cost differentiation. Second, with more domestic products, diversion following a tariff is spread across a larger set of goods, and with more imports, strategic complementarity may be amplified, resulting in higher prices. Third, demand curvature may either attenuate or amplify passthrough and impact the optimal policies chosen by the planner. All of these forces interact, making the optimal policies nontrivial.

Balanced Government Budget Suppose that we now enforce a balanced budget constraint by recycling tariff revenue into domestic subsidies on marginal costs. The social planner maximizes the sum of consumer surplus, domestic producer surplus, and externalities subject to the budget constraint. Denote the Lagrangian multiplier on the budget constraint as $\lambda \geq 0$. The planner's first-order conditions are identical to those of the unconstrained planner, with one key modification. The fiscal terms (tariff revenue and subsidy expenditure) are scaled by λ, the shadow value of public funds. The remaining terms retain their original weights. The multiplier λ controls the degree to which the planner internalizes the fiscal consequences of policy decisions.

Remark 1. *The unconstrained planner achieves the first-best solution. This serves as a natural benchmark for the remainder of our analyses. Imposing a balanced budget constraint introduces a shadow cost of public funds, $\lambda \geq 0$. When $\lambda = 1$, the budget constraint is not distortionary, and the optimal policies coincide exactly. This is a knife-edge solution: generally, $\lambda \neq 1$, and the constrained solution yields a second-best outcome. When $\lambda \neq 1$, the planner effectively over- or under-weights the revenue and expenditure sides of the budget, distorting policy away from the unconstrained solution.*

Discussion The theoretical results, formalized in Appendix A, jointly characterize the optimal design of trade and industrial policy in oligopolistic markets with differentiated products. The results are related to the canonical work in Brander and Spencer (1985); we consider a richer setting with simultaneous tariff and subsidy instruments and endogenous revenue feedback. Proposition 1

recovers the optimal tariff and describes the conditions under which the optimal tariff is positive. Broadly, positive tariffs are warranted when domestic profit gains and fiscal revenue outweigh the consumer cost of higher prices. But, the usual intuition breaks down under sufficiently convex demand, wherein sufficiently more-than-complete passthrough moves to an upward sloping portion of the Laffer curve. This echoes the results in Goldberg and Hellerstein (2013) and Miravete, Seim, and Thurk (2023), which show that the curvature of demand is essential in determining optimal tariff rates.

Proposition 2 establishes a similar result for optimal subsidies. Optimal subsidies are positive when consumer surplus gains from subsidy passthrough exceed any additional fiscal expenditures from volume expansions. Similar to Barwick, Kwon, and Li (2024), we characterize the optimal subsidies, though we omit dependence on attributes. Revenue recycling, which constrains the social planner's budget by funding subsidies with tariff revenue, interacts with the shadow value of public funds and passthrough regimes such that recycling can either tighten or relax optimal policies, as shown in Corollary 1.

Finally, Proposition 3 characterizes when the two policy instruments act as substitutes or complements, with the distinction governed by cross-instrument passthrough ratios that measure how much each policy bleeds into the other's welfare margin. Close substitutability and convex demand push the policies towards substitutes, while product differentiation and concave demand preserve orthogonality of the instruments. Our findings are similar to those in Einav et al. (2025), which studies the coordination of policies in health markets: combinations of policies (complementarity) or better-targeted policies can achieve higher levels of welfare. The global automobile market, and the EV market specifically, is characterized by substantial product differentiation, cost differences, and complex interactions of policies, making it a perfect testing ground for our theoretical work.

2.2 Monte Carlo Simulations

We evaluate optimal tariffs and subsidies in a tractable simulation environment to sharpen the theoretical insights.

Environment There is a unit mass of consumers with utility for product j given by:

$$u_{ij} = -\alpha_i(1 + \tau \times 1\{j = f\})p_j + \delta_j + \varepsilon_{ij},$$

where heterogeneous price sensitivity is given by $\alpha_i = \bar{\alpha} + \sigma_p \nu_i$ with $\nu \sim N(0,1)$. Products are assumed to be type-symmetric, i.e., domestic products have the same utility and imported products have the same utility. We assume that $\varepsilon \sim$ T1EV, so market shares s_j take a (mixed) logit form. There is a set of N_d symmetric domestic firms and a set of N_f symmetric import firms characterized

by their marginal costs c_d, c_f, respectively. We set $c_d = c_f = 1$, $\alpha = 3$, $\delta_d = \delta_f = 1$, $\sigma_p = 0.75$, and $N_d = 5$ throughout. Unless otherwise noted, we set $N_f = 1$. A key feature of this environment is that consumers face an ad valorem tariff τ on imports, while the subsidy σ is applied to the marginal cost of domestic goods.

Optimal Policy Mix Figure 2 compares four scenarios: (i) unconstrained use of both tariffs τ and subsidies σ, (ii) tariff τ only ($\sigma = 0$), (iii) subsidy σ only ($\tau = 0$), and (iv) revenue recycling in which tariff revenues finance subsidies with a balanced budget constraint. The figure plots welfare over the policy space.[5] Revenue recycling achieves welfare nearly identical to that of the unconstrained planner and selects close to the same policy pair. The intuition follows directly from the theoretical model. In the unconstrained problem, the planner's first-order conditions equate the marginal benefit of the tariff to its marginal cost in social surplus; the subsidy first-order conditions operate similarly. Revenue recycling does not fundamentally alter these tradeoffs; instead, the government budget constraint merely transfers tariff revenue to the subsidy, leaving the planner free to choose a (τ^*, σ^*) that is mostly unaffected.[6]

Tariffs alone perform the worst. Without a subsidy, every increase in τ imposes a larger deadweight loss on consumers who shift away from imports that they value. Subsidies alone outperform tariffs but are less effective than the combined policies.[7] Figure 3 reinforces this by displaying the iso-welfare curves in (τ, σ) space.

Figure 4 decomposes welfare into consumer surplus, domestic profits, and government revenue as functions of τ at the optimal subsidy, separately for the no-recycle and recycle regimes. In the no-recycle case (left panel), consumer surplus falls steeply in τ because consumers bear a large portion of the incidence of the tariffs due to passthrough. Domestic profits rise modestly because domestic firms capture only a fraction of the diverted import demand. Government revenue is negative because the expenses from the optimal subsidy to domestic firms are higher than revenues collected from tariffs on imports, only becoming positive at moderate tariff levels. The tension between these forces is clear in Figure 2. Revenue recycling (right panel) changes the picture in a few ways. First, government revenue is mechanically zero because revenue recycling transfers all tariff proceeds back to domestic firms as subsidies to marginal costs. Second, the transfer flattens

[5] For (i), the figure shows welfare conditional on the tariff rate while solving for the optimal subsidy. Given that both are freely optimized, the maximum is isomorphic to whether it was plotted over subsidies instead. For (iii), welfare is plotted over subsidies, and for (iv), welfare is plotted over tariffs, which are again isomorphic with subsidies given the balanced budget.

[6] The results depend on market structure. When there are fewer imports, i.e., a smaller base for tariffs and their funded subsidy counterparts, the solution falls farther away from the unconstrained planner's optimum. Intuitively, this changes the shadow value of public funds in the balanced budget case, which can shift the optimal policies in ambiguous directions.

[7] This finding is for a fixed market structure; there are some scenarios in which tariffs alone outperform subsidies alone.

out the consumer surplus curve relative to the no-recycle case, even generating an increase in consumer surplus for low tariff rates. Domestic firms receiving the subsidy pass through a portion of cost savings (sometimes overshifting) in the form of lower prices, meaning consumer surplus is compensated even as τ rises. The net effect is that welfare declines more slowly with τ under revenue recycling, pushing the optimal tariff somewhat higher than the no-recycle case.

These patterns also show why revenue recycling achieves nearly the same optimum as the unconstrained planner. The unconstrained planner wants high subsidies, but these subsidies require government expenditure for which tariff revenue is a natural source. That is, revenue recycling pays a "double dividend" to consumers and domestic firms.

Demand Curvature Now that we have examined the baseline environment, we explore the relationship between optimal policies and demand curvature. Figure 5 compares the BLP (random coefficients logit) specification to a simple logit specification ($\sigma_p = 0$). Notably, tariffs under BLP demand (Panel A) are higher than under simple logit (Panel B). Under BLP, optimal tariffs decline monotonically in N_f/N_d, the ratio of the number of imported goods to domestic goods, with and without revenue recycling. Under logit, revenue recycling again yields a declining τ^* curve, but omitting revenue recycling now produces an increasing optimal tariff curve. The intuition connects to the theoretical prediction that demand curvature shapes the consumer surplus cost of tariffs. Under simple logit, the consumer surplus loss is mostly netted out by tariff revenues, which increase with more imports, yielding an upward-sloping optimal tariff curve. Under BLP, the consumer surplus losses are sufficiently large that the optimal tariff curve is decreasing instead. Appendix B provides additional simulations in which we explore optimal policies over market structure, the degree of product differentiation, and cost differences between imports and domestic goods.

Discussion The simulation evidence underscores three lessons from the theory. First, the complementarity between tariffs and subsidies can be significant. Neither instrument alone achieves the welfare of the combined policies, and revenue recycling nearly replicates the unconstrained planner in certain circumstances. Second, incorporating rich preference heterogeneity via random coefficients yields qualitatively different optimal policies than simple demand curvature in a logit specification. Third, the direction of the relationship between market structure, product differentiation, or cost differences and optimal policies can reverse entirely depending on whether revenue is recycling. This reinforces the nuances required when empirically evaluating trade and industrial policies.

3 Background and Data

3.1 Chinese EVs Around the World: Penetration and Entry Barriers

Chinese automakers are playing an increasingly important role in the global EV market. In 2023, China's EV leader BYD sold 2.26 million battery electric vehicles, accounting for 12.1% of global BEV sales, and surpassed Tesla as the world's largest BEV producer. At the same time, Chinese EV producers increasingly supply EV models with relatively high quality at low prices.

However, the global reach of Chinese EVs differs sharply across markets because policy barriers also vary significantly. The US, despite being an early leader in EV adoption, has increasingly become a laggard along two margins: EV penetration remains relatively low, and the market is now one of the least open major destinations for Chinese EVs. We summarize these cross-market differences in policy barriers and Chinese EV penetration below.

United States. The US is the most restrictive case. In 2024, it raised the Section 301 tariff on Chinese EVs from 25 percent to 100 percent, bringing the total tariff burden to 102.5 percent with 2.5 percent MFN tariff included. The US policy has also expanded beyond tariffs toward non-tariff restrictions, especially through regulations on connected vehicles using Chinese software or hardware. In practice, these measures move US policy closer to a *de facto* ban. Consistent with this policy stance, Figure 1 shows that the share of China-manufactured EVs in the US market remains essentially zero throughout the sample.

Canada. Canada has adopted a similarly restrictive stance until the end of 2025. It has imposed a 100 percent surtax on Chinese-made EVs, which, combined with the standard 6.1 percent MFN tariff, raises the total tariff burden to 106.1 percent. However, this policy stance shifted markedly in late 2025, when Canada and China reached a new arrangement allowing an annual quota of 49,000 Chinese EVs to enter at the regular 6.1 percent MFN tariff rate. This shift suggests a partial reversal of Canada's earlier restrictive stance and points to a more open policy direction going forward.

European Union. The European Union has taken a more moderate approach. Rather than imposing a prohibitive uniform tariff, it introduced countervailing duties on EVs produced in China, with total tariff rates varying across firms and ranging from 17.8 percent to 45.3 percent. This leaves the E.U. more open than the US and Canada. Figure 1 shows that the share of China-manufactured EVs in the E.U. rises steadily after 2020, but still faces significant restrictions on market access.

Australia. Australia is the least restrictive market in our comparison. It has not imposed special punitive tariffs on Chinese EVs, and tariffs on passenger motor vehicles have already been phased down to zero. As a result, Chinese EV producers face few border-policy barriers in Australia relative to other major developed markets. Figure 1 shows that Australia has experienced by far the fastest growth in the share of China-manufactured EVs, reaching more than 30 percent by 2024.

Another consequence of barriers to Chinese EV entry in the US market is higher EV prices. Table E.1 shows that, relative to ICE models, EV MSRPs were substantially lower in China. After accounting for government subsidies, consumer prices of EVs in China were already on par with, or even below, those of ICE models. In contrast, in North America and the E.U., EV prices remained approximately 27 percent higher than comparable ICE models even after subsidies.

3.2 Data

We compile several comprehensive datasets that encompass the global automobile industry.

Global Automobile Sales and Attributes. We compile automobile sales and attribute data for 13 countries, covering major automobile markets from 2004 to 2023 and including the critical period of the global EV transition.[8] Our automobile sales data is sourced from the MarkLines database, which covers the annual sales of all vehicle fuel types for all major countries since 2004. The 13 countries we focus on accounted for 85% of global ICE sales and 95% of EV sales during the sample period. We augment MarkLines with complementary data sources for validation and to adjust for statistical definitions to ensure cross-country comparability.[9]

Our vehicle attributes data comes from multiple sources. The major source is the Teoalida Car Database. We complement key attributes with other attribute databases, including IHS Markit data, Ward's Automotive for the US, and EV Volumes. Additionally, we manually collect attributes for fringe models in the Chinese market from various automobile forums.

EV Battery Suppliers and Incentives. The EV battery supplier data is collected and compiled using the Battery Cell/Module data from the MarkLines database. For each EV model, we observe the name of the battery supplier (e.g., CATL) and products (e.g., lithium iron phosphate battery cell, known as Blade).

We collect and extend the worldwide EV incentive data based on Barwick et al. (2023). We manually collected and compiled a large set of policy documents to calculate both financial incen-

[8]The 13 countries are Austria, Canada, China, France, Germany, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, the U.K., and the US

[9]The complementary data sources include China Automotive Technology and Research Center (CATARC) national vehicle sales from 2012 to 2018, MarkLines's China monthly registration from 2020 to 2023, and IHS Markit used in Barwick et al. (2025).

tives (e.g., tax credits, subsidies) and non-financial incentives (e.g., green plates, parking benefits, HOV lane access). The final data contains total monetary incentives for EV consumers at the country, year, and model levels.

Tariffs and Industrial Policies. We construct a comprehensive dataset on trade barriers and industrial policies. First, we manually collect bilateral automobile tariff data for the sample countries through various sources, including news reports, government policy documents, and WTO tariff schedules. Second, for industrial policies, we utilize the dataset constructed in (Barwick et al., 2024).

Auxiliary Data. We incorporate several auxiliary data sources. First, for the income distributions used in demand estimation, we collect socioeconomic variables and annual household income statistics by country from the World Inequality Database (WID).[10] Second, to construct micro-moments for demand estimation, we combine household survey data on new vehicle buyers from China (2018–2020) and the US (2018) (Leard, Linn, and Springel, 2024; Barwick et al., 2025). Third, to illustrate the rise in protectionism, we manually collected historical trade tariff data and non-trade policy barriers between major countries.

4 Empirical Model

We develop an empirical model of demand and supply for the global automobile industry. Each period, heterogeneous consumers demand vehicles, and firms set prices for their existing vehicle models. Firms choose which electric vehicle models to introduce across and within markets.

4.1 Demand

Consumer i in market m (i.e., a country) chooses a vehicle j from the product set $\mathscr{J}_{mt} = \{0, 1, ..., J_{mt}\}$ that includes both EVs and ICEs. Consumers choose the outside option $j = 0$ if they do not buy a new vehicle. The utility of consumer i from purchasing vehicle model $j \neq 0$ in market m in year t is given by:

$$u_{ijmt} = -\alpha_{im}\left(\tilde{P}_{jmt} - b_{jmt}\right) + \mathbf{X}_{jmt}\beta_{im} + \eta_{jmt} + \gamma_{ijmb} + \xi_{jmt} + \varepsilon_{ijmt}. \tag{4}$$

The utility of the outside option is normalized to $u_{i0mt} = \varepsilon_{i0mt}$ for all i, m, t. The consumer price $\tilde{P}_{jmt}$ follows the notation in Barwick, Kwon, and Li (2024) in which taxes are incorporated. Consumers pay the price net of government subsidies b_{jmt} for EVs. The vector $\mathbf{X}_{jmt}$ includes product

[10] WID can be accessed at https://wid.world/.

characteristics; η_{jmt} include a rich set of fixed effects, and γ_{ijmb} captures brand loyalty (see below). The term ξ_{jmt} is the unobserved quality of the vehicle or demand shock, and ε_{ijmt} is the idiosyncratic preference shock, assumed to be distributed Type I Extreme Value.

The price coefficient is specified as $\alpha_{im} = \bar{\alpha} + \alpha_m / y_{im} + \sigma^p \nu_{im}^p$, where $\bar{\alpha}$ is the average price sensitivity across markets. Price sensitivity depends on consumer household income in country m, denoted y_{im}. We allow the coefficient on income to differ across countries and classify them into four groups based on country median income: $\{\alpha_1, \alpha_2, \alpha_3, \text{ and } \alpha_4\}$.[11] This specification guarantees that the (dis)utility of price is homothetic in income.[12] We assume ν_{im}^p follows a standard log-normal distribution and σ^p captures heterogeneity in price sensitivity.

The parameters $\beta_{im} = \{\beta_{imk}\}_{k=1}^K$ represent heterogeneous preferences for K vehicle attributes with mean component $\bar{\beta} = \{\beta_k\}_{k=1}^K$. The preference for attribute k in market m is defined as $\beta_{imk} = \bar{\beta}_k + \sigma_m^k \nu_{im}^k$. We assume ν_{im}^k follows a standard normal distribution and σ_m^k captures heterogeneity in preferences for each market.

The extension of our model relative to the standard Berry, Levinsohn, and Pakes (1995) framework is that we include consumer-specific brand preferences, γ_{ijmb}, as a component of random utility. We specify it as a random coefficient on the market-brand fixed effect $\gamma_{ijmb} = \sigma_m^b \nu_{ijm}^b$ to capture heterogeneity in within- and cross-brand substitution patterns. We assume ν_{ijm}^b follows a standard normal distribution as before, but restrict values to be the same for all models j of the same brand b for a given individual i. Allowing for $\sigma_{bm} \nu_{ijm}^b$ is important for firms' product entry decisions. For example, a larger σ_m^b indicates stronger within-brand preference, implying weaker cross-brand substitution—so substitution is more likely to occur within the firm, such as from its ICE models to newly introduced EV models. Brands within a given market share the same σ_m^b, but we allow σ_m^b to vary across markets.

We decompose utility in Equation (4) as is standard in the literature. Denote the mean utility as $\delta_{jmt} = \mathbf{X}_{jmt}\bar{\beta} + \eta_{jmt} + \xi_{jmt}$ and the individual-specific utility as $\mu_{ijmt} = -\alpha_{im}\left(\tilde{P}_{jmt} - b_{jmt}\right) + \sum_k \sigma_k x_{jkt} \nu_{im}^k + \sigma_{mb} \nu_{ijm}^b$. Under the assumption that the idiosyncratic preference shocks ε_{ijmt} are

[11] The classification follows an ascending order of income: Group 1 = China, Group 2 = Japan, Spain, France, and Germany, Group 3 = United Kingdom, Netherlands, Australia, and Sweden, and Group 4 = Canada, Norway, United States, and Switzerland.

[12] We find that making the utility function homothetic to the scale of price and income is crucial to the estimation of demand because global to nominal prices and income do not impact vehicle demand. For instance, the US $ appreciated against other currencies in 2014, causing both the nominal price and income in other nations that are denoted in US $ to drop significantly. Our specification allows for this exchange rate shock to impact vehicle demand through real terms $(\tilde{P}_{jmt} - b_{jmt})/y_{im}$ but not nominal terms.

distributed Type I Extreme Value, quantities sold for product j in market m at time t is:

$$q_{jmt} = M_{mt} \int \frac{\exp(\delta_{jmt} + \mu_{ijmt})}{1 + \sum_{j' \in \mathscr{J}_{mt}} \exp(\delta_{j'mt} + \mu_{ij'mt})} dF(\mu_{ijmt}), \tag{5}$$

where M_{mt} is the market size of country m at time t, and $\int \frac{\exp(\delta_{jmt}+\mu_{ijmt})}{1+\sum_{j' \in \mathscr{J}_{mt}} \exp(\delta_{j'mt}+\mu_{ij'mt})} dF(\mu_{ijmt})$ are market shares that are computed by integrating individual choice probabilities.

4.2 Supply

On the supply side, automakers set prices for all models in each country to maximize profits, taking their product portfolios as given. Firm f chooses prices in country m at time t:

$$\pi_{fmt}(\mathscr{J}_{mt}) = \max_{\{p_{jmt}; j \in \mathscr{J}_{fmt}\}} \sum_{j \in \mathscr{J}_{fmt}} (p_{jmt} - mc_{jmt}) \cdot q_{jmt}(p_{jmt}, \mathbf{p}_{-j,mt}) \qquad \forall m \in 1, ..., M, \tag{6}$$

where $\mathbf{p}_{-j,mt}$ is the price vector for all other products except for j and mc_{jmt} is the marginal costs. At this stage, firms have complete information about product sets, product attributes, rival pricing strategies, demand shocks, and cost shocks. Additionally, firms account for government policies, such as subsidies for EVs and bilateral tariffs.

We assume automakers play a static Nash-Bertrand game in equilibrium pricing. Assuming the existence of a pure-strategy equilibrium, the price of any product j produced by firm f must satisfy the first-order condition (FOC). For simplicity, we drop the market-time subscript mt. The FOC with respect to the price of product j is:

$$q_j + \sum_{k \in \mathscr{J}_f} (p_k - mc_k) \frac{\partial q_k}{\partial p_j} = 0$$

This equation illustrates that a multi-product firm internalizes the cross-price effects (cannibalization) among its own products.

To solve for the equilibrium prices, we can stack the first-order conditions into matrix notation. Let Δ be a $J \times J$ ownership and substitution matrix with its (j,k)-th element defined as:

$$\Delta_{jk} = \begin{cases} -\frac{\partial q_k}{\partial p_j} & \text{if products } j \text{ and } k \text{ are produced by the same firm} \\ 0 & \text{otherwise} \end{cases}$$

Using this matrix, the system of first-order conditions can be expressed in vector form as:

$$\mathbf{q} - \Delta(\mathbf{p} - \mathbf{mc}) = 0$$

Inverting the Δ matrix yields the equilibrium price vector $\mathbf{p}^*$ as a function of marginal costs and the equilibrium markup:

$$\mathbf{p}^* = \mathbf{mc} + \Delta^{-1}\mathbf{q} \tag{7}$$

where $\Delta^{-1}\mathbf{q}$ represents the vector of optimal markups for all products in the market. With the estimated demand parameters, we use Equation (7) to recover the marginal cost of each vehicle model in each market.

In the baseline estimation, tariffs do not enter firms' pricing decisions. In the counterfactual simulations, we assume the US government imposes an ad valorem tariff on Chinese EVs. Appendix C.1 derives the corresponding pricing equilibrium when an importer is present.

4.3 Estimation and Identification

Aggregate Moments and Instruments To address the potential endogeneity of prices raised from unobserved product quality and demand shocks ξ_{jmt}, we introduce instrumental variables (IVs) for identification. We use three sets of instruments. The first set of instruments follows the standard Berry, Levinsohn, and Pakes (1995) approach. We include: the number of rival brands, the count of models of own brand and rival brands, the count of models of own brand in other markets, and the average model characteristics of own and rival brands. We use "differentiation IVs" from Gandhi and Houde (2019) as our second set of instruments. We use the "local distance" suggested by Conlon and Gortmaker (2020), which measures the number of products in the same pre-defined market scope that are within one standard deviation of a given attribute.[13] The last set of instruments is a battery IV to capture exogenous upstream supply shock following Barwick, Kwon, and Li (2024). We construct these as the interaction between battery capacity and dummies of battery suppliers for each EV model.

We denote our instruments as vector $\mathbf{Z}_{jmt}$ and exogenous product attributes as $\mathbf{X}_{jmt}$, and construct the aggregate moment condition:

$$\mathbb{E}\left[\xi_{jmt} \mid \mathbf{Z}_{jmt}, \mathbf{X}_{jmt}\right] = 0.$$

[13] To construct the instrument, we define the scope of competition as the same country, year, segment, and fuel type. The set of attributes used includes: displacement, horsepower, footprint, driving range, and battery capacity.

Micro-Moments We additionally include micro-moments to help our identification of preference parameters. We use two sets of micro-moments. The first set of micro-moments matches the observed average income of households that purchase a specific vehicle model (both EV and ICE) with the income predicted by the demand model. We use household surveys in China and the US to calculate the average household income for 45 popular vehicle models in China from 2018 to 2020 and 79 popular models in the US in 2018. This gives us 124 micro-moments.

The second set of micro-moments targets EV consumers. We use data on income distribution among EV buyers from Canada (2013), Germany (2013), Norway (2014), Japan (2015), Sweden (2015), and the Netherlands (2019) and match the observed share of EV buyers within specific income brackets to the corresponding model-predicted share.[14] We use two-stage GMM and follow Conlon and Gortmaker (2025) in the construction of the variance-covariance matrix and gradients of the aggregate moments and micro-moments.

4.4 Demand Estimation Results

Table 1 reports parameter estimates for global automobile demand. There are a total of 65,574 observations across 13 major countries of the global automobile market from 2004 to 2023. Column (1) shows results for the OLS multinomial logit model that does not include any instruments. Column (2) includes instruments for prices using the set of instruments described above. Notably, the price coefficient is significantly more negative in Column (2), highlighting the problems encountered with a positive correlation between prices and unobserved product attributes. The signs of the remaining coefficients have intuitive signs: consumers prefer home brands, and more horsepower, fuel economy, and size. For electric vehicles, consumers prefer longer driving ranges. All coefficients are precisely estimated.

Column (3) includes random coefficients in the model to incorporate heterogeneous preferences across individual consumers. The signs of the coefficients match those in Column (2). We find significant dispersion parameters for many coefficients, a few of which we highlight. First, the random coefficient on the EV indicator is large, meaning that preferences for EVs are heterogeneous. Second, the dispersion parameters on income-price interactions vary significantly. The parameter for JP/SP/FR/DE is the largest, followed by that of CHN. These two groups of countries have the largest income effects. The coefficients for UK/NL/AT/SE and CA/NO/US/CH are much smaller. All of the income coefficients are positive, meaning that high-income households are less price-sensitive than their lower-income counterparts. The set of random coefficients on brand

[14] These data are collected from the literature and include five income groups in Canada, four in Germany, six in Norway, five in Japan, three in Sweden, and four in the Netherlands. Since income groups are mutually exclusive, we drop one group per country, resulting in 21 micro-moments for this category.

preferences warrants further discussion because it governs within-brand substitution patterns. The coefficient for US+CA is the largest, followed by smaller markets in the EU. This is consistent, for example, with the story of the Big Three in the US in which the three largest firms dominate the market and there is likely strong within-brand substitution. The coefficient for CHN and larger markets in the EU are much smaller, consistent with more market fragmentation and less strong brand preferences.

We present a histogram of own-price elasticities in Panel (a) of Figure D.4. The average price elasticity is -2.62, which falls roughly in line with the existing literature on combined EV and ICE demand (Grieco, Murry, and Yurukoglu, 2024). This is consistent with previous estimates of global EV demand elasticity, typically ranging from -2 to -4 (Barwick et al., 2025; Li et al., 2017) because EV buyers tend to have higher incomes and are less price-sensitive.

Panel (b) shows a set of price semi-elasticities against consumer-facing prices (net of subsidies and incentives) by country groups. The semi-elasticity is the percentage change in sales for a \$1,000 decrease in a given vehicle model's consumer-facing price. The semi-elasticities are larger in magnitude for less expensive vehicles. This is consistent with the income coefficients in the estimated preference parameters and higher demand elasticities. The intuition is that consumers who buy these vehicles typically have lower incomes.

5 Optimal EV Tariffs with Revenue-Funded Subsidies

5.1 Introducing Chinese EVs to the US Market

Top Chinese-Manufactured EV. We exogenously introduce a fixed set of Chinese EV models into the US choice set. Specifically, we focus on the top 10 China-manufactured EV models ranked by their market shares in China in 2023. We use 2023 as the baseline year throughout the counterfactual analysis and treat these models' observed 2023 characteristics as the baseline attributes for the introduced products.[15]

Our counterfactual framework abstracts from endogenous entry decisions.[16] We select the top 10 models in the Chinese market because they are commercially important, widely adopted, and thus provide a transparent and policy-relevant set of potential entrants. Importantly, these are mainstream, high-volume models produced by major incumbent automakers (e.g., BYD, SAIC,

[15]The list of the top 10 Chinese EV models used in our counterfactual entry exercise is reported in Table E.3. To provide context on which models are being introduced and how prominent they are in their home market, Figure D.5 shows the market shares of the top 50 Chinese EV models in China. The top 10 models together account for 34.3% of the Chinese EV market.

[16]In a follow-on project, we are estimating the fixed costs of EVs and endogenizing the product entry and exit decisions.

and GAC), rather than niche models from smaller, newer EV startups.[17] The maintained assumption is that, if US restrictions on Chinese EVs were lifted, these "off-the-shelf" models would be among the most likely candidates to enter the US market. As a robustness check, we repeat the analysis using the top 10 China-manufactured EV models that are currently sold in Europe.

Constructing Mean Utility. A key challenge in our counterfactual analysis is that Chinese-branded EV models are not observed in the US market in the estimation sample.[18] Consequently, we must take a stance on the level of US consumers' mean utility for Chinese EVs. For each Chinese model $j \in \mathscr{F}^{\text{CN}}$ produced by a Chinese automaker and introduced in our counterfactual, we specify the mean utility in the US market as:

$$\delta_{j,\text{US}} = \mathbf{X}_{j,\text{US}}\bar{\boldsymbol{\beta}} + \eta_{j,\text{US}} + \xi_{j,\text{US}}, \qquad j \in \mathscr{F}^{\text{CN}}, \tag{8}$$

where $\mathbf{X}_{j,\text{US}}$ is the observed product-characteristics vector, $\eta_{j,\text{US}}$ is a product fixed effect capturing persistent components of mean utility, and $\xi_{j,\text{US}}$ is the remaining demand unobservable. For the first component, we assume that the observable characteristics of a Chinese model are the same in the US as in its home market, $\mathbf{X}_{j,\text{US}} = \mathbf{X}_{j,\text{China}}$.

We then construct the fixed effect $\eta_{j,\text{US}}$ using information from models that are observed in both markets and are produced by non-Chinese automakers. Specifically, we assume that the US fixed effect for a Chinese model equals its China-market fixed effect plus an additive adjustment that captures the average cross-country difference in fixed effects for comparable products:

$$\eta_{j,\text{US}} = \eta_{j,\text{China}} + \kappa_{g(j)}. \tag{9}$$

Here $g(j)$ indexes the aggregation level used to form the adjustment. In our baseline specification, $g(j)$ is the model's powertrain type (EV, ICE, HEV, or PHEV), so the adjustment is common across all models within the same power type.

We estimate κ_g from products observed in both countries that are produced by non-Chinese automakers. Let $\mathscr{J}^{\text{obs}}$ denote the set of models observed in both China and the US in our estimation sample. Then

$$\kappa_g = \mathbb{E}\Big[\eta_{j',\text{US}} - \eta_{j',\text{China}} \mid g(j') = g,\ j' \in \mathscr{J}^{\text{obs}},\Big], \quad g \in \{\text{EV}, \text{ICE}, \text{HV}, \text{PHEV}\}. \tag{10}$$

[17] As highlighted in Wang and Xing (2025), fringe models produced by EV startups are more likely to suffer from reputational concerns about quality and are therefore more likely to exit the market.

[18] Although Volvo is owned by Geely, we treat Volvo as a non-Chinese brand in our baseline because it is marketed and perceived as a European brand in our data.

This construction implies that the mean utility of an entering Chinese EV in the US inherits its relative positioning in the China market through $\eta_{j,\text{China}}$, while allowing for a systematic cross-country shift in valuation captured by κ_g.[19]

For the third component, $\xi_{j,\text{US}}$, our baseline approach sets it equal to the corresponding unobservable estimated in the home market, $\xi_{j,\text{China}}$. As a robustness check, we instead draw ξ from the empirical distribution of estimated demand shocks in China and find that the resulting counterfactual outcomes are very similar. We also consider an alternative set of draws based on the empirical distribution of ξ among models sold in the US market.

Constructing Marginal Costs. In this paper, we study automobile trade rather than foreign direct investment: we assume that Chinese EV models are produced in China and exported to the US market, as opposed to a scenario in which Chinese brands establish production facilities in the US.[20] Under this trade environment, imported Chinese EVs face ad valorem tariffs upon entry into the US. In our counterfactual simulations, we model these policies as (i) an ad valorem tariff applied to the consumer price of Chinese EVs and (ii) additional per-vehicle cost components that shift marginal cost, including international shipping and US-side distribution and marketing expenses.

Although we cannot directly estimate the marginal costs of Chinese EVs in the US market for models that are not yet sold in the US, we observe a set of Chinese EV makes and models that are sold in both China and the US. We use the estimated cross-country marginal-cost gap for these overlapping models to discipline the marginal-cost level of the counterfactually introduced Chinese models in the US market. In doing so, we account for tariffs and other per-vehicle trade costs. The assumption is that the observed difference in recovered marginal costs across the two markets provides an empirical analogue for the additional cost wedge associated with serving the US market from China.

We calibrate per-vehicle shipping costs at \$2,750 and additional US-side distribution and marketing costs at \$1,402. These magnitudes are consistent with industry benchmarks and practitioner estimates of shipping and downstream selling costs in the global automobile market.

[19] As a robustness check, we consider several alternative ways of constructing κ, including using different aggregation levels for $g(\cdot)$. In addition, we implement an alternative approach that does not rely on a China-to-US shift. Specifically, we use the distribution of estimated fixed effects in the observed US market to impute $\eta_{j,\text{US}}$ for entering Chinese EVs: we assign $\eta_{j,\text{US}}$ to the 25th or 75th percentile of the US fixed-effect distribution (within the relevant product group). The resulting estimates and implied counterfactual outcomes are qualitatively similar across these alternatives.

[20] In comparison, Head et al. (2026) study endogenous global supply networks and production relocation in the EV battery industry.

5.2 Measuring Welfare Effects of Chinese EV Entry

Given the constructed marginal costs, mean utilities, and policy parameters, we re-solve the Nash-Bertrand pricing equilibrium in the US market after introducing the Chinese EV models and compute the equilibrium outcomes of interest, including sales-weighted average prices, market shares, and welfare measures.[21] We define the change in welfare under each counterfactual scenario relative to the 2023 status quo as,

$$\Delta\text{Welfare} = \Delta CS + \Delta\Pi^{US} + \Delta\text{GovRevenue} + \Delta\text{EnvBenefits}, \tag{11}$$

where total welfare consists of consumer surplus (CS), US producers' profits (Π^{US}), government revenue, and environmental benefits.

Consumer surplus is computed using the standard random-coefficients logit formula. Dropping subscripts (m,t) for simplicity, we write

$$CS = \int \frac{1}{\alpha_i} \log\Big(1 + \sum_{j \in \mathscr{J}} \exp(\delta_j + \mu_{ij})\Big)\, dF(\mu_{ij}) \; + \; \text{constant}, \tag{12}$$

where α_i is the individual-specific marginal utility of price, δ_j is mean utility and μ_{ij} captures heterogeneous tastes. The additive Euler constant term cancels out when we take differences, so it plays no role in ΔCS.

We measure environmental benefits from policy-induced changes in the reduction in ICE sales. Specifically, we convert the change in equilibrium ICE sales into avoided lifetime external damages from (i) UnitCarbCost: CO_2 emissions (climate damages) and (ii) UnitHealthCost: local air pollution (health damages). Let ΔQ^{ICE} denote the change in total ICE sales relative to the 2023 status quo. We then compute

$$\Delta\text{EnvBenefits} = -\Delta Q^{ICE} \cdot \big(\text{UnitCarbCost} + \text{UnitHealthCost}\big), \tag{13}$$

where UnitCarbCost and UnitHealthCost are per-vehicle lifetime external costs (in thousands of dollars per vehicle). Borrowing the results from Funke et al. (2023), we calibrate UnitCarbCost $=$ 3.810 ($1,000) and UnitHealthCost $=$ 0.687 ($1,000) for the US

[21] We solve the Nash-Bertrand pricing equilibrium using the algorithm suggested in Morrow and Skerlos (2011).

5.3 The Effect of Tariff-Recycling Subsidy

Figure 6 shows the decomposition of welfare and its relationship with tariff rates under the top-10 Chinese EV entry scenario, comparing the cases with and without tariff-revenue recycling. Under the tariff-recycling regime, each candidate tariff is matched to the subsidy level implied by the government balanced-budget constraint, where tariff revenue exactly finances subsidy expenditure.[22] We then compute the optimal tariff with a revenue-funded subsidy by searching over a tariff rate grid. Several findings stand out.

First, social welfare is hump-shaped in the tariff rate under both policy regimes, implying that the optimal tariff is strictly positive rather than zero. Thus, once Chinese EV entry is allowed, some degree of protection remains welfare-improving, but excessively high tariffs become counterproductive. The welfare-maximizing tariff is lower under tariff recycling (25.0 percent) than under the no-recycling case (27.5 percent), indicating that a less aggressive tariff is needed once tariff revenues are returned as domestic EV subsidies.

Second, tariff recycling shifts the welfare frontier upward and performs substantially better in sustaining EV adoption. Relative to tariffs alone, recycling delivers higher welfare across nearly the entire tariff range. At the same time, for any given tariff rate, EV market share remains markedly higher when tariff revenues are recycled into domestic EV subsidies, showing that recycling better preserves electrification while still limiting Chinese EV penetration.

Third, the gains from tariff recycling arise primarily because it better preserves consumer surplus and EV adoption while also improving US producer profits relative to the no-recycling case. More broadly, the figure highlights the government's fundamental trade-off: policies aimed at protecting domestic producers and advancing industrial policy objectives tend to come at the expense of consumer surplus and environmental benefits when implemented through tariffs alone. Recycling tariff revenues helps relax this trade-off by partly offsetting domestic producers' losses without sacrificing as much consumer surplus and electrification.

Figure D.8 reports the decomposition when only the top 5 Chinese EV models are introduced. The qualitative patterns remain broadly consistent. Two differences are worth noting. First, when the number of Chinese EV entrant models is smaller, the welfare-maximizing tariff under both policy regimes is higher. Second, with only five Chinese EV models, the optimal tariff under tariff recycling (32.5%) is higher than under the no-recycling regime (30.0%).

Figure 7 shows the market outcomes and welfare effects under the optimal tariff-recycling subsidy policies. Allowing Chinese EVs to enter the US market substantially expands EV adoption and generates large welfare gains. In the benchmark case with the top 10 Chinese EV models, the

[22] We then solve for the corresponding price equilibrium for each tariff-subsidy combination.

optimal policy combines a 25 percent tariff with a recycling subsidy of $7.5 thousand per vehicle. Relative to the status quo, this policy increases EV sales by 118.7 percent and lowers the average EV price by 25.7 percent. These effects translate into a $45.62 billion increase in consumer surplus, reflecting both a broader EV choice set and access to more affordable models. The decline in domestic firm profits remains modest, as the recycling subsidy partly offsets the losses induced by Chinese EV entry. As the number of Chinese EV entrant models increases, the optimal tariff and the associated recycling subsidy both decline. Thus, while broader Chinese EV entry continues to improve market outcomes, the optimal tariff-recycling policy becomes less aggressive as entry expands.

5.4 Mechanisms: Pass-through and Markups

Policy Pass-through. To understand why tariff-revenue-funded subsidies improve consumer surplus and aggregate welfare, we calculate the corresponding pass-through rates for both the tariff and subsidy components, as pass-through is a first-order determinant of aggregate outcomes in counterfactual trade policy experiments (Head and Mayer, 2026). As the tariff in our simulation is ad valorem, we measure tariff pass-through as the change in consumer prices relative to the change in realized tariff payments per vehicle, dP/dT.[23] For the recycling-based subsidy, we analogously define pass-through as the reduction in consumer prices relative to the increase in per-vehicle subsidy expenditure. Appendix C.2 provides the full formal information of the pathway when the policy applies to multiple products that incorporate strategic price responses.

Figure 8 reveals a clear asymmetry in policy pass-through across the two groups. Chinese entrant EVs exhibit incomplete pass-through, meaning that only a fraction of the per-vehicle tariff payment is transmitted into consumer prices. In other words, Chinese EV makers absorb part of the tariff burden through lower markups rather than fully passing it on to consumers. The use of ad valorem tariffs plays an important role, as the tax-incidence literature suggests that they can be more likely than specific taxes to generate incomplete pass-through under imperfect competition (Delipalla and Keen, 1992; Anderson, De Palma, and Kreider, 2001).[24] Intuitively, firms compress

[23] In the standard additive-cost case, pass-through is typically defined as the extent to which policy-induced changes in firms' effective marginal costs are transmitted into consumer prices, as measured by Δprice/Δmarginal cost; See Weyl and Fabinger (2013) and Miravete, Seim, and Thurk (2023).

[24] Under an ad valorem tariff, consumer prices satisfy $P = (1+\tau)x$, where x is the tax-exclusive price chosen by the firm, and per-vehicle tariff payments are given by $T = \tau x$. Hence $\frac{dP}{dT} = 1 + \frac{dx/d\tau}{x+\tau dx/d\tau}$. If firms optimally reduce tax-exclusive prices when tariffs rise, $dx/d\tau < 0$, implying that pass-through with respect to tariff payments is below one. This attenuation channel is specific to ad valorem tariffs because tariff payments themselves depend on firms' tax-exclusive pricing decisions. By contrast, if the tariff were imposed as a specific (per-unit) tariff, the corresponding pass-through rate would tend to be higher. We prove the relation between unit-specific tariff and ad valorem tariff passthrough formally for a single product firm in Appendix C.2.

tax-exclusive markups to limit the loss of demand and market share, so part of the tariff shock is absorbed by firms rather than fully transmitted into consumer prices. Because tariff pass-through is incomplete, the optimal ad valorem tariff on Chinese EVs is strictly positive. This result arises from the rich income heterogeneity embedded in our demand system (Head and Mayer, 2026). By contrast, in the CES monopolistic-competition framework commonly used in trade economics, tariff pass-through is unitary (See Appendix C.3). Under that benchmark, the optimal tariff is zero.

By contrast, US-branded EVs that receive domestic-content subsidies display persistent over-shifting of the recycling-based subsidy. In other words, domestic EV prices fall by more than the increase in per-vehicle subsidy expenditure, reflecting strong strategic pricing responses on the subsidy-receiving side of the market. This finding is in line with Goldberg and Hellerstein (2013) and Miravete, Seim, and Thurk (2023), which show that pass-through in mixed logit models with rich consumer heterogeneity tends to be more than complete.

Taken together, these two patterns illustrate the dual advantage of the tariff-recycling policy: incomplete tariff pass-through on Chinese entrant EVs and more-than-complete subsidy pass-through on US-branded EVs. As a result, the policy raises the prices of foreign entrants while lowering the prices of domestic EVs. Domestic consumers therefore benefit from subsidy-induced EV price reductions while bearing only part of the tariff-induced price increase.

Market Structure and Markups. To understand the mechanism through which tariff-recycling subsidies interact with market structure, Figure 9 illustrates the simulated relationships among pricing, markup, demand curvature, and market power for individual vehicle models following Chinese EV entry into the US market. Panels (a) and (b) plot markup against price under the no-policy benchmark and the tariff-recycling subsidy policy, respectively. Panels (c) and (d) plot demand curvature against the Lerner index under the same two scenarios.

Focusing first on the no-policy benchmark, Chinese entrant EVs are concentrated in a region characterized by relatively low prices but high markups. Despite their low absolute prices, these models enjoy substantial local market power because their price advantage leaves them with few close competitors in the relevant part of the product space, resulting in relatively high Lerner indices. At the same time, their estimated demand curvature is comparatively low, indicating that demand elasticity remains relatively stable over the relevant price range. As illustrated schematically in Figure D.9, this corresponds to the low-price, high-market-share region of the demand curve, where the composition of marginal consumers changes relatively little with price.

By contrast, US incumbent EVs tend to face substantially higher demand curvature, which helps explain why subsidy pass-through for US-branded EVs is more likely to be high and, in some cases, exceed one. Prior to the subsidy, these models primarily serve relatively high-income

consumers with low price sensitivity. Once the subsidy is introduced, however, the relevant demand becomes more elastic as additional middle-income consumers are drawn into the market. In other words, the subsidy changes not only the level of prices but also the composition of the potential consumer base faced by US EV producers. As illustrated in Figure D.9, US incumbent EVs are located closer to the "elbow" of the demand curve, where a relatively small change in price leads to a sharp shift in the composition of consumers.

These two patterns are consistent with the pass-through and demand-curvature mechanisms emphasized in the literature (Goldberg and Hellerstein, 2013; Miravete, Seim, and Thurk, 2023). Chinese entrant EVs combine high local market power with relatively low demand curvature, making lower tariff pass-through more likely, as firms have both the ability and the incentive to absorb part of the tariff shock through markup compression. This pattern is also consistent with De Loecker et al. (2016), who documents incomplete pass-through following trade reform. By contrast, US incumbent EVs face substantially higher local curvature, making higher subsidy pass-through more likely. The resulting asymmetry highlights how market power and demand curvature jointly shape pricing responses in a flexible demand environment.

Comparing the no-policy benchmark with the tariff-recycling subsidy policy further clarifies the mechanism. Once the policy is introduced, Chinese entrant EVs move toward a region with lower markups, lower Lerner indices, and higher curvature. This shift is consistent with the idea that tariffs weaken their local price advantage and erode part of their market power. In contrast, US incumbent EVs move in the opposite direction: the recycling subsidy lowers effective consumer prices, improves their competitive position relative to Chinese entrants, and tends to place them in a region where subsidy pass-through remains strongly above one. The overall implication is that the tariff-recycling policy reshapes the competition and reallocates market power across product groups by compressing the markups of Chinese entrant EVs while strengthening the pricing position of US incumbent EVs. This is why the joint policy is effective in reshaping relative prices and competitive outcomes: it reduces the profitability of foreign entry while simultaneously amplifying the consumer-facing benefits of domestic EV subsidies.

5.5 Optimal Policy Design

We next characterize the optimal policy design over a menu of feasible policy regimes. we focus on four policy tools: a subsidy-only policy, a tariff-only policy, an unconstrained joint policy that combines both instruments, and the tariff-recycling subsidy policy that we propose, under which tariff revenues are rebated to domestic EV producers. The last regime is of particular interest because it may be more politically feasible. Figure 10 plots the welfare surface over a two-dimensional policy space, with the ad valorem tariff on Chinese EVs on the horizontal axis and the per-unit

subsidy to US domestic EVs on the vertical axis. Two main findings emerge.

Relationship Between Tariffs and Subsidies as Policy Tools. Tariffs and domestic subsidies act as substitutes in the optimal policy mix. The red dashed and dotted lines show that, as the tariff rate increases, the subsidy required to maximize welfare declines; conversely, as the subsidy increases, the welfare-maximizing tariff also declines. Intuitively, both instruments improve the competitive position of domestic EVs relative to Chinese entrant EVs, so the marginal value of one instrument falls as more of the other is used. As the two instruments are substitutes, the optimal policy problem is to choose the most effective combination of the two.

Appendix Figure D.10 illustrates this substitutability more directly. When the tariff increases from 0% to 100%, the welfare-maximizing domestic subsidy declines. The intuition is that, once the subsidy exceeds its optimal level, the marginal benefit of further subsidy expansion—through additional consumer surplus and environmental gains—becomes smaller than its marginal cost, including higher government spending and the induced change in domestic firm profits. At the same time, the magnitude of this decline depends on the underlying market structure, in particular on the number of Chinese EV entrant models. When Chinese entry is limited, the optimal subsidy changes relatively little across tariff regimes. By contrast, when Chinese entry is broader, the reduction in the optimal domestic subsidy is more pronounced, because the tariff already provides a greater degree of protection and market reallocation, reducing the additional subsidy needed to maximize welfare.

Comparing Across Optimal Policy Scenarios. Tariff recycling closely approximates the globally optimal policy mix and is more politically feasible. In the benchmark case with the top 10 Chinese EV entrants, the unconstrained welfare maximum is attained at a tariff of 22.5% and a subsidy of $8.4 thousand per vehicle. This policy dominates both the subsidy-only regime, which requires a larger subsidy of $9.6 thousand, and the tariff-only regime, which requires a higher tariff of 27.5%. Along the balanced-budget recycling constraint, the optimal recycling policy sets a 25.0% tariff and a subsidy of $7.47 thousand. This allocation lies close to the unconstrained optimum in the policy space and delivers nearly identical welfare. The main implication is that tariff recycling captures most of the gains from the unconstrained optimum under a more implementable financing rule.

Figure D.11 extends this comparison across alternative policy regimes and different numbers of Chinese EV entrants. For each entry case, we compute the welfare-maximizing tariff by grid search under both non-recycling and recycling regimes. The recycling policy consistently lies close to the global optimum and generally dominates the single-instrument alternatives, including tariff-only, subsidy-only, and quota policies. Appendix Figures D.12 shows that the same pattern

holds for $N = 5$ and $N = 20$. The exact tariff under recycling can be either slightly above or slightly below the unconstrained optimum, but the distance in welfare terms remains small.

Table 2 provides a richer comparison across optimal policy regimes for the benchmark $N = 10$ case. The unconstrained joint policy delivers a welfare gain of \$45.72 billion, while the optimal recycling policy delivers \$45.62 billion. Relative to the tariff-only regime, recycling raises EV adoption from 16.06% to 19.69%, increases environmental benefits from \$3.66 billion to \$5.51 billion, and reduces the decline in US firm profits from \$-8.49 billion to \$-2.81 billion. Thus, tariff recycling preserves nearly all of the welfare gains from the globally optimal policy mix while providing substantially more protection for domestic producers than tariffs alone. Recycling policy may also be more politically feasible than either the subsidy-only regime or the unconstrained global optimum, because it avoids the large government outlays required under those alternatives (\$14.77 billion and \$3.01 billion, respectively).

6 Evaluation of Current and Alternative US Policy Scenarios

In our final empirical exercise, we move from optimal policy design to policy evaluation and study the welfare and distributional consequences of introducing Chinese EVs into the US market under a range of current and alternative policy scenarios.

6.1 Market Outcomes and Welfare Effects

Policy Scenarios. We examine a range of scenarios under alternative US-China tariff rates and US domestic subsidy schemes. The baseline scenario in Column (1) assumes that no Chinese EVs can enter the US market (the Chinese EV ban), which mimics the current situation. To compare the welfare gain from lifting the Chinese EV ban with the only EV subsidy, Column (2) maintains the ban but provides a \$7,500 EV incentive to all EV models produced by US-domestically manufactured automakers, mimicking the domestic-content subsidy under the Inflation Reduction Act. The remaining columns lift the ban and exogenously introduce the top 10 most popular Chinese EV models into the US market. These columns explore different combinations of trade and subsidy policies.

Columns (3) to (6) consider alternative tariff policies. Specifically, Column (3) represents a scenario with no additional tariffs beyond the standard 2.5% tariff. Column (4) adds a 25% tariff, corresponding to the tariff level during the first wave of the US–China trade war under the first Trump administration. Column (5) adds a 100% tariff, corresponding to the more recent EV tariff level under the early Biden administration. Column (6) considers a more protectionist industrial policy scenario in which tariff revenues collected on Chinese EVs are fully recycled as additional

subsidies for US domestic EV manufacturers (GM, Ford, Tesla, etc.), reflecting the "tariffs-as-revenue" philosophy associated with the second Trump administration.[25]

Column (7) considers a quantity-based trade policy. Specifically, it grants a tariff-free quota for the first 0.5 million units of Chinese EV imports, followed by a 102.5% tariff on any units exceeding the quota. This scenario is intended to mimic the type of Canada-China EV regime, hypothetically applied to the US context.

In the last column, we consider a scenario in which Chinese EVs are introduced while US-domestically manufactured EVs continue to receive a $7,500 subsidy, aligning with an industrial policy aimed at fostering the domestic EV industry.

Results. Table 3 reports the results. Panel A shows the effect on market outcomes, including price and EV adoption rate. Panel B reports the effects on changes in each component of welfare.

Several findings emerge from simulating the effects of adding Chinese EVs. First, introducing Chinese EVs into the US market substantially increases EV adoption and lowers EV prices. The EV share rises from 9% in the status quo to 18.2% under the minimum-tariff scenario, and then gradually declines to 11.6% as tariffs increase. The tariff-recycling subsidy and quota policies fall in the middle of this range. The free-trade scenario combined with a domestic industrial policy in Column (8) delivers the highest EV share. In the status quo, incumbent non-Chinese EVs sold in the US are priced about $9,500 higher than comparable ICE vehicles, which helps explain the relatively low EV adoption rate in the US status quo. Adding Chinese EVs substantially reduced the average EV prices. The price effects are driven largely by product compositions. The introduced Chinese EV models are priced well below incumbent US EVs and ICE vehicles due to their substantially lower marginal costs, based on our estimates.

Second, the distribution of producer surplus provides a clear economic rationale for imposing tariffs on Chinese EVs. Under the low-tariff scenario (2.5%), Chinese EVs capture nearly 70% of the US EV market and generate about $28 billion in profits. This reallocation of market share is accompanied by sizable losses for domestic producers and a decline in manufacturing employment: the model implies roughly 87 thousand fewer US manufacturing jobs relative to the status quo.[26] As tariffs increase, Chinese EVs lose market share but remain competitive. Even under the

[25] For a given tariff rate, to implement the revenue-recycling scenario, we solve for the implied subsidy under a balanced-budget constraint by searching over a subsidy grid and selecting the value that exhausts tariff revenue.

[26] We construct an approximate measure of US auto manufacturing employment implied by each counterfactual by mapping equilibrium sales into domestically produced units and then into jobs. We classify domestic producers into (i) US-headquartered automakers and (ii) incumbent foreign-owned "transplant" automakers. For US firms, we assume 75% of US sales are produced domestically; for transplants, we assume 53% production happens in the US (Source: American Automakers). We then convert domestically produced units into jobs using a constant jobs-per-vehicle coefficient calibrated from aggregate data. We set the ICE coefficient to 0.10 jobs per vehicle, calculated as payroll employment in motor vehicles and parts (about 1 million jobs; Source: FRED) divided by US

most aggressive tariff (102.5%), Chinese EVs still account for about 30.6% of the US EV market. This finding suggests that, absent additional frictions, tariffs alone would not fully prevent Chinese EV entry and that non-tariff barriers likely contribute to the de facto ban observed in the data. Finally, when tariff revenues are recycled as additional subsidies to US domestic EV manufacturers, Chinese EV market share falls further to below 20%, highlighting that targeted industrial policy can more effectively limit foreign penetration than tariffs alone. Overall, these results underscore that protecting domestic producer rents and domestic employment is an important motivation for the high tariffs imposed on Chinese EVs.

The first two main findings highlight the fundamental trade-off underlying barriers against Chinese EVs. On the one hand, allowing Chinese EV entry accelerates fleet electrification and benefits consumers by expanding the choice set and lowering prices. On the other hand, it harms domestic EV automakers by eroding their market shares.

Third, in terms of Δ welfare, introducing the top 10 Chinese EV models increases social welfare by more than \$30 billion across all policy scenarios. The welfare gains are driven primarily by higher consumer surplus, reflecting the availability of new and more affordable EV models. The main losers are US domestic automakers, which experience revenue losses as Chinese EV entrants capture market share.

The largest welfare gain arises under the combined trade-and-domestic-subsidy scenario. One major concern with this policy, however, is that without endogenous innovation and product repositioning, domestic ICE models face intensive competition from both Chinese EVs and subsidized domestic EVs, leading to substantial declines in ICE sales and profit and correspondingly large manufacturing job losses.

Conditional on using trade policy alone, the highest welfare is achieved under the mild tariff, followed by the 0.5 million-unit quota, and then the no-additional-tariff case. The aggressive tariff regime delivers the lowest welfare gain, while recycling tariff revenues increases welfare by about 13%. With only tariffs (Columns (3)-(5)), US domestic automakers lose profits in both the ICE and EV segments. In contrast, under the tariff-recycling subsidy policy, US domestic automakers gain \$7.3 billion in EV profits while losing \$4.2 billion in ICE profits, implying a positive net change in domestic profits. The implied decline in US manufacturing employment also narrows to about 11,000 jobs. As a result, the tariff-recycling subsidy delivers moderate welfare gains while largely avoiding losses to domestic automakers' profits. Therefore, this policy is close to a

light-vehicle production in 2023 (about 10 million units; Source: FRED). Finally, we assume EV assembly to be less labor-intensive by scaling the ICE coefficient by 0.70 (i.e., 30% fewer assembly workers for EVs, as suggested by Weng et al. (2024)). The resulting job measure is the sum of jobs attributed to domestic production by US firms and incumbent transplants, and job changes are reported relative to the 2023 status quo.

win-win outcome in our simulations, as it raises consumer surplus while also improving domestic automakers' net profits. In this scenario, the primary losers shift to incumbent non-US automakers (e.g., European, Korean, and Japanese firms).

As a robustness check, we consider an alternative set of entrants. In Table E.2, we use the top ten China-manufactured EV models currently sold in Europe as the potential entrants. The qualitative findings remain consistent, although the magnitudes are roughly half as large. Figure D.7 reports results under alternative procedures for constructing the fixed effects and ξ components in mean utility. Figure D.6 shows the simulated EV share from 2014 to 2023 under the scenarios above.

6.2 Winners and Losers

Households by Income Distribution. Table 4 reports EV adoption and welfare changes by income quartile, with Q4 representing the wealthiest households. The scenarios generate markedly different distributional consequences. Consistent with common critiques of federal EV subsidies, the IRA-style subsidy is regressive in our simulations: it raises EV adoption and delivers larger welfare gains for higher-income households. The mechanism is straightforward—under the status quo, EVs are concentrated in the higher end of the price distribution, so a uniform EV subsidy disproportionately accrues to consumers who are already more likely to purchase an EV.

In contrast, introducing Chinese EV models produces a more favorable outcome from an equity standpoint. The gains are more evenly distributed across the income distribution and are particularly pronounced for households in the middle of the distribution (especially Q3). This pattern reflects product composition: the introduced Chinese EV models are priced closer to mainstream ICE vehicles than to incumbent EV models, which expands the EV choice set for middle-income households that are priced out of incumbent EVs in the status quo. As a result, Chinese EV entry increases adoption among households that would otherwise purchase ICE vehicles, shifting the distribution of benefits away from the top of the income distribution.

Firms. Figure 11 summarizes firm-level winners and losers by plotting changes in EV profits (vertical axis) against changes in ICE profits (horizontal axis) under four counterfactual policies. Consistent with the discussion above, Chinese EV entry generally harms incumbent producers because it substitutes away from both incumbent ICE models and EV models. Even under the aggressive tariff scenario (top left), all incumbent automakers experience profit losses in both segments. Tesla is the largest loser given its heavy exposure to the EV market.

The distribution of gains changes sharply when tariff revenue is recycled into domestic EV subsidies (top right). In this case, Tesla becomes a clear winner due to its high exposure to the

subsidy. GM and Ford also shift into positive EV-profit territory despite continued losses on ICE sales. Under the subsidy-only scenario without Chinese entry (bottom left), most incumbents see modest EV profit gains that are partly offset by declines in ICE profits, leaving GM and Ford with little change in total profits. When Chinese EVs are introduced alongside the subsidy (bottom right), domestic ICE products face substantial profit losses from intensified competition from both Chinese EVs and subsidized domestic EVs. For GM and Ford, the EV profit gains are no longer sufficient to offset the larger losses from ICE.

Overall, scenarios with subsidies disproportionately benefit firms with a larger EV footprint, with Tesla emerging as the largest winner. GM and Ford tend to gain in EVs while losing in ICEs, and the EV gains are often insufficient to fully offset the ICE losses. Incumbent non-US automakers (European, Japanese, and Korean firms) experience profit declines in both EV and ICE segments.

7 Conclusion

While the US was a pioneer in the transition to electrified transportation in the early 2010s, domestic EV adoption has recently stalled, leaving the country lagging behind leaders like China and the EU. This paper proposes a policy package designed to put the US back on track by allowing the entry of low-cost, high-quality Chinese EVs subject to a welfare-maximizing tariff, while simultaneously recycling those revenues into consumer subsidies for domestically produced EVs. Our analysis demonstrates that this integrated approach effectively manages the core trade-off between aggressive climate goals and the protection of the domestic manufacturing sector. By leveraging an optimal tariff of approximately 25% to fund subsidies of nearly $7,500 per domestic vehicle, the US can more than double its EV market share and generate over $45 billion in annual social welfare gains.

The findings of this study underscore the importance of nuanced policy design that accounts for market dynamics such as demand curvature and asymmetric firm pass-through. We show that the "hump-shaped" nature of the welfare function necessitates a carefully calibrated optimal tariff to avoid the counterproductive effects of excessive protectionism. Furthermore, our results highlight that the optimal policy is sensitive to the variety of imported models; as more models enter, the resulting consumer surplus gains typically lead to a lower optimal tariff rate. Ultimately, this research provides a viable roadmap for the US to accelerate its energy transition through strategic trade and industrial policy, ensuring that environmental progress does not come at a steep expense of domestic industry.

This study takes existing US product offerings as given and allows certain Chinese models

to enter the US market; as such, the findings should be viewed as short-run impacts. To capture longer-run effects, future research should endogenize model entry decisions while allowing US automakers to respond with more aggressive EV product offerings in the face of more intensive competition. While the voluntary export restraints of the 1980s were intended to protect the market share of US automakers, they ultimately catalyzed the rise of transplant facilities as Japanese firms bypassed export quotas by shifting production to the US. As global recognition of Chinese EVs grows alongside their market share, these firms may similarly establish manufacturing bases within the US or the broader Americas. How production locations and supply chains evolve in response to trade barriers remains a critical research question for the next phase of the energy transition.

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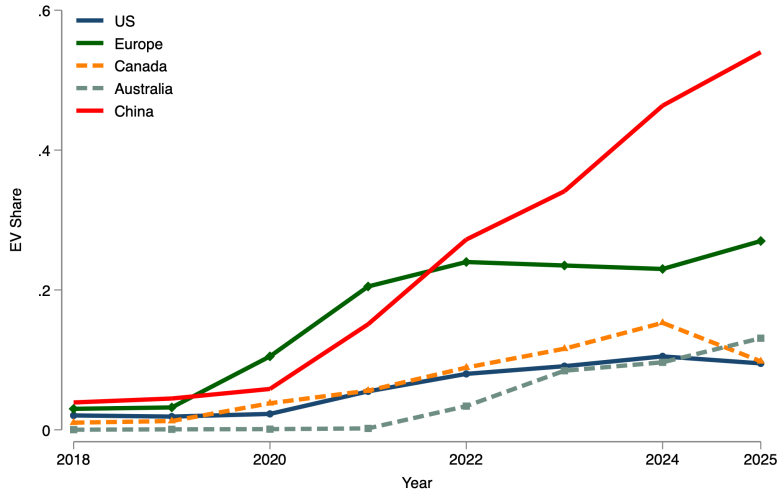
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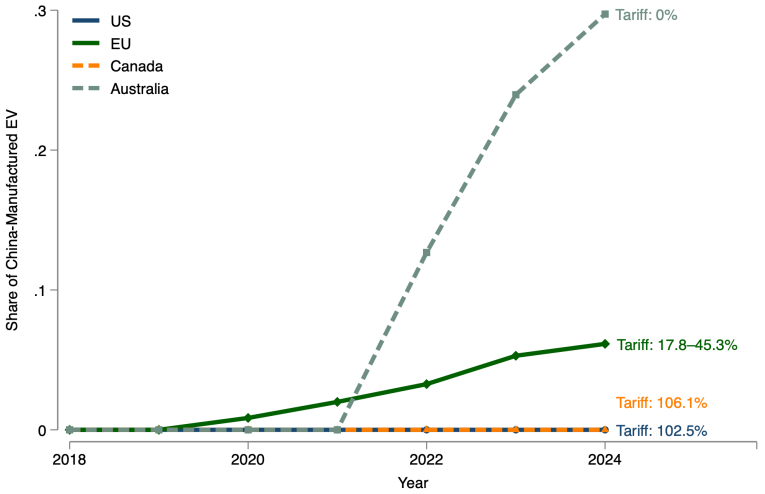
Figures & Tables

Figure 1: Global Electric Vehicle Adoption and the Rise of China-Manufactured EVs

(a) EV adoption across markets

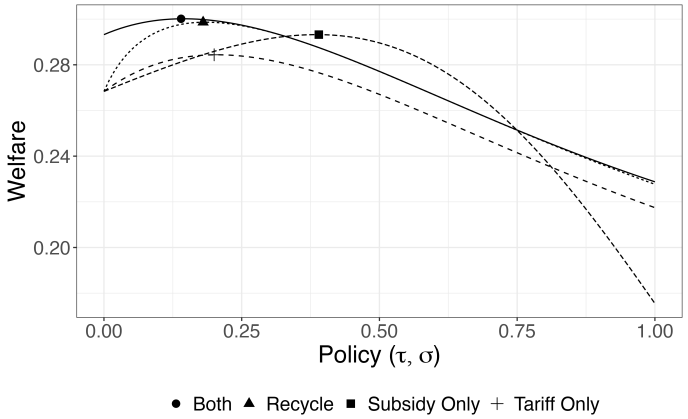


(b) Share of China-manufactured EVs of total EV



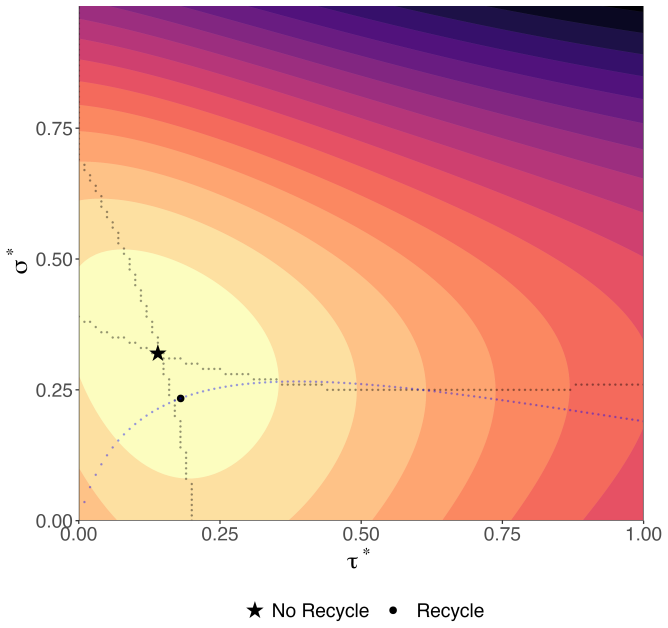
Notes: This figure shows the trends in EV adoption and the market penetration of China-manufactured EVs across major global markets from 2018 to 2024. Panel (a) displays the EV adoption rate, defined as the share of new EV registrations in total passenger vehicle sales. The lines represent the US, EU, Canada, and Australia (plotted against the left axis), while the bars represent China's EV adoption rate (plotted against the right axis). Panel (b) shows the share of China-manufactured EVs out of total new EV sales in each destination market. We regard Volvo as a non-Chinese brand in this calculation. The annotations highlight the corresponding import tariff rates on Chinese EVs effective in 2024: 0% for Australia, 17–38% for the EU, and 100% for both the US and Canada.

Figure 2: Welfare by Policy Mix



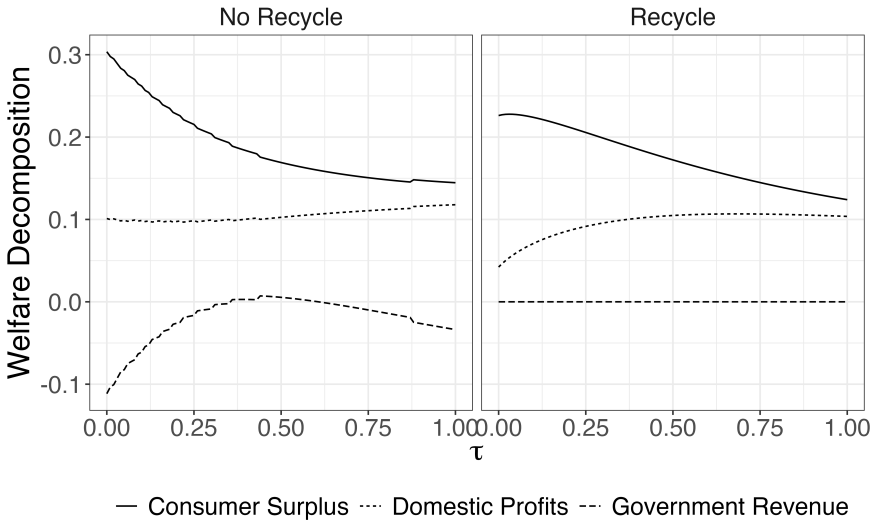
Notes: This figure shows optimal policies in the baseline simulation environment with $N_f = 5$. There are four scenarios: (i) unconstrained tariffs and subsidies (Both, dot); (ii) tariffs only (Tariff Only, cross); (iii) subsidies only (Subsidy Only, square); and (iv) revenue recycling (Recycle, triangle). The curves plot welfare on the y-axis over the policy levels (tariffs for (i), (ii), and (iv), subsidies for (iii)). The unconstrained planner achieves the highest welfare, but revenue recycling is close. Policies are different for the tariff and subsidy only scenarios, and lead to less welfare.

Figure 3: Iso-Welfare Curves in Policy Space



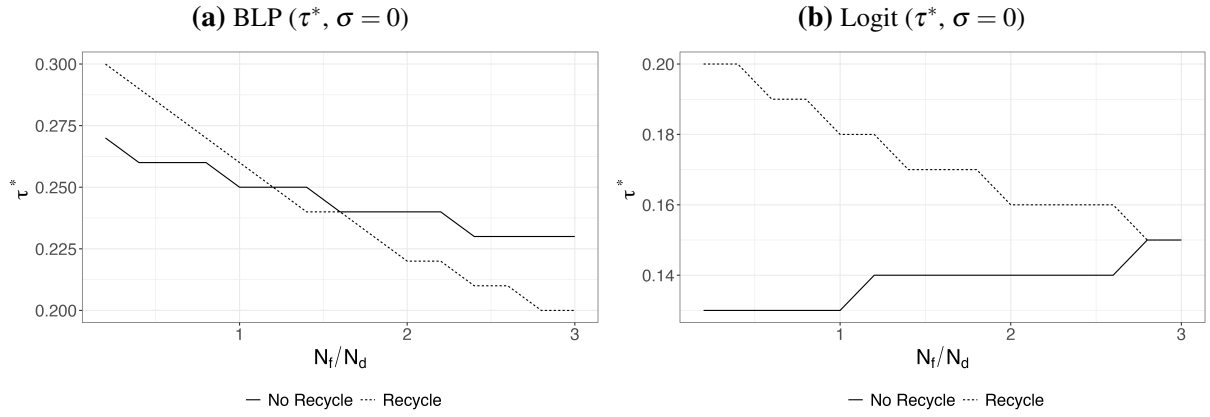
Notes: This figure shows iso-welfare curves and optimal policies in the baseline simulation environment with $N_f = 15$. The contours represent welfare levels, with lighter hues corresponding to higher welfare. The x-axis is the tariff rate, and the y-axis is the subsidy. The star is the unconstrained planner's solution, and the dot is the balanced budget planner's solution. The vertical dotted line is the optimal tariff, fixing subsidies; the horizontal dotted line is the optimal subsidy, fixing tariffs; and the blue dotted line is the optimal subsidy under revenue recycling, fixing tariffs. Revenue recycling achieves close to the unconstrained solution.

Figure 4: Welfare Decomposition



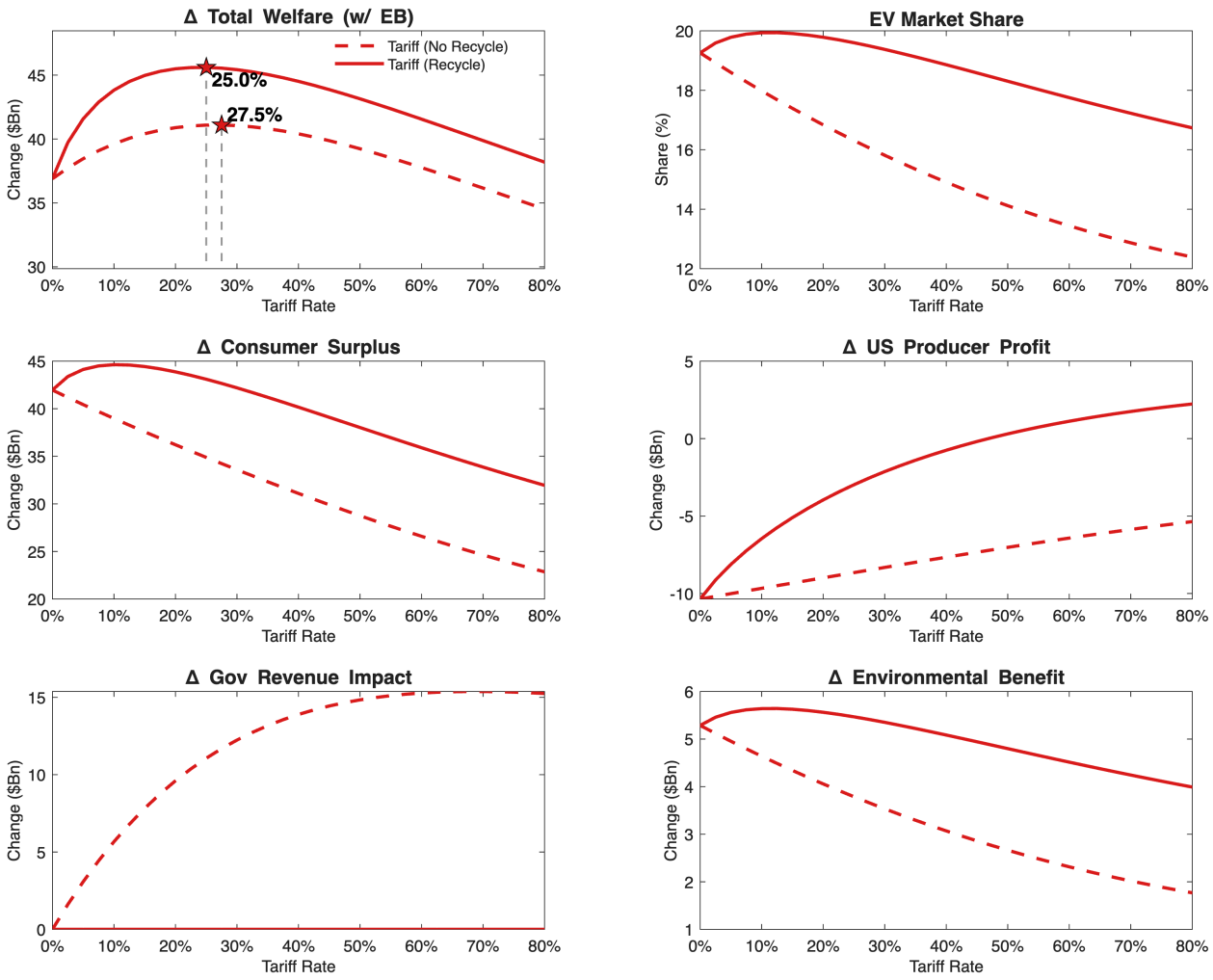
Notes: This figure decomposes the sources of welfare in the baseline simulation environment with $N_f = 15$. The left panel is the unconstrained planner, and the right panel is the revenue recycling (budget-constrained) planner. The y-axis is the welfare level, and the x-axis is the fixed tariff rate. The left panel shows the unconstrained planner sacrifices government budget to improve domestic profits, and has a steep gradient in consumer surplus losses. The right panel shows the revenue recycling planner does not have to sacrifice as much marginal consumer surplus, and can still improve domestic firms' profits.

Figure 5: Optimal Policies by Demand Specification



Notes: This figure shows optimal policies over market structure by demand curvature. The left panel uses BLP and the right panel uses logit. The solid lines are the tariff-only solutions, and the dotted lines are the revenue recycling solutions. The y-axis is the optimal tariff rate, and the x-axis represents market structure as the ratio of imports N_f to domestic goods N_d. In the BLP specification (left), the planners set tariffs that are decreasing in the number of imports, and the tariff curve decreases faster for revenue recycling. In the logit specification (right), the revenue recycling planner still decreases tariffs, but the tariff-only planner sets higher tariffs when there are more imports.

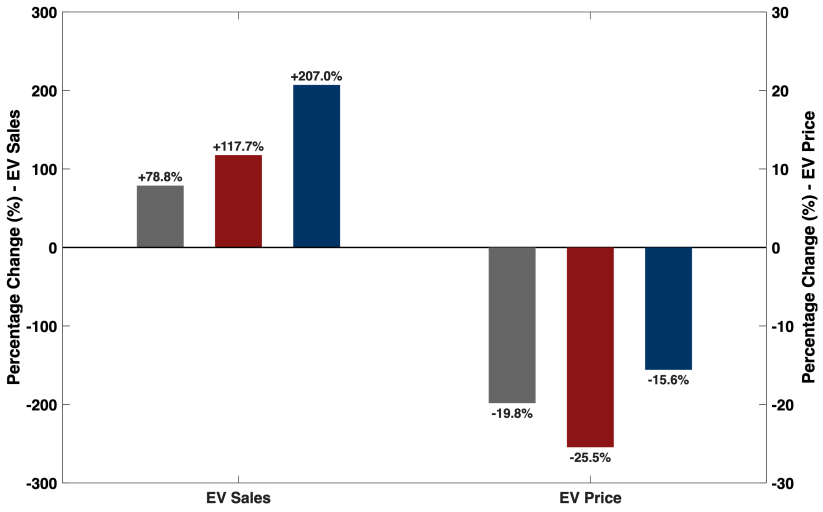
Figure 6: Decomposition of Welfare and Relationship with Tariff Rates



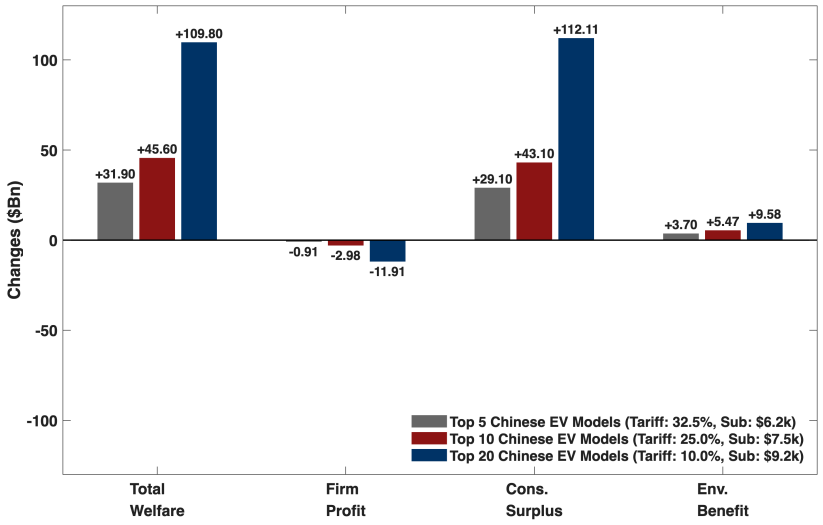
Notes: This figure illustrates the simulated changes in social welfare components and market outcomes relative to the 2023 status quo, following the introduction of the **top 10** Chinese-manufactured EV models into the US market. In each panel, the red solid line represents the scenario with tariff revenue recycling into domestic EV subsidies, while the red dashed line represents the scenario without such recycling. The stars in the Total Welfare panel indicate the optimal tariff rates that maximize social welfare under the two respective policy regimes. All monetary values are measured in $billions.

Figure 7: Market Outcomes and Welfare Effects under Optimal Tariff-Recycling Subsidies

(a) EV Adoption and EV Price



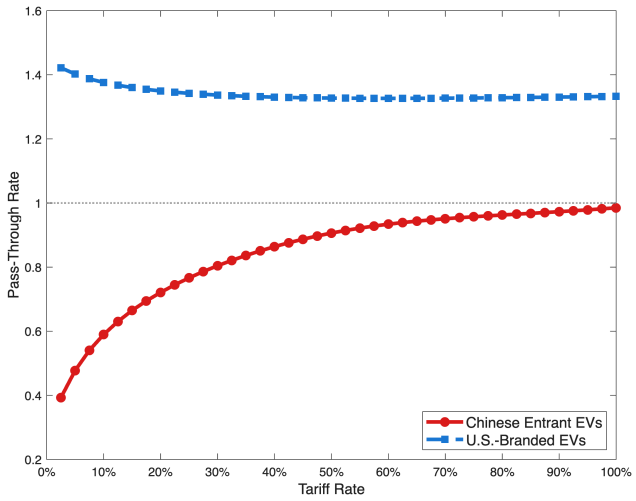
(b) Welfare



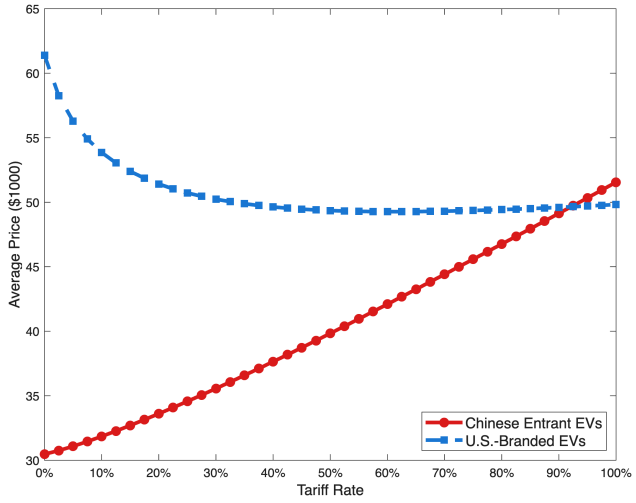
Notes: This figure shows market outcomes and welfare effects under the optimal tariff-recycling subsidy policies. All outcomes are reported relative to the 2023 status quo baseline. Panel (a) reports percentage changes in EV sales and the sales-weighted average EV price. The left set of bars shows the EV sales (read on the left axis), and the right set of bars shows the EV price (read on the right axis). Panel (b) reports changes in welfare components in $billions. Bars report changes in total welfare, firm profits, consumer surplus, and environmental benefits. Bars with different colors correspond to the three entry cases shown in the legend (introducing the top 5, top 10, or top 20 Chinese EV models).

Figure 8: Aggregated Pass-Through Rates and EV Price along with Tariff Rates

(a) Pass-Through Rates

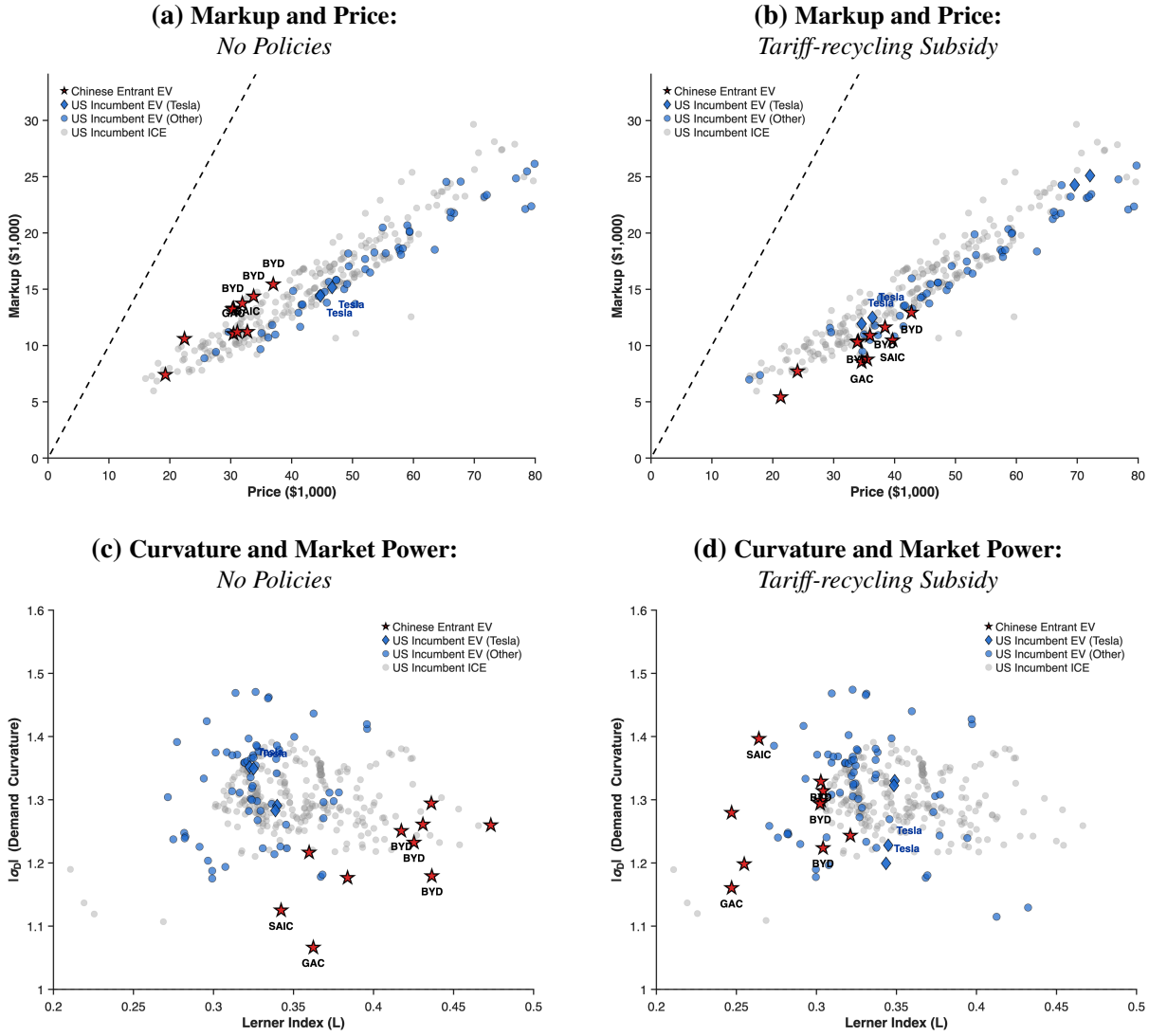


(b) Average EV Price



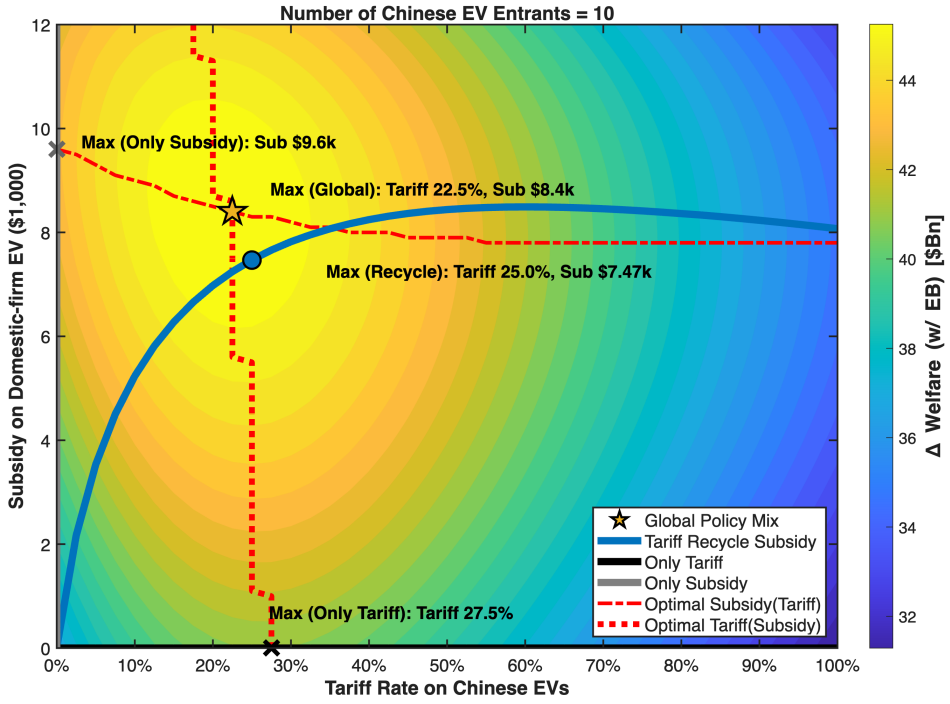
Notes: This figure displays the simulated market responses under the joint policy scenario of tariffs on Chinese EVs and a recycling-based subsidy for US domestic EVs. All simulations are conducted using 2023 as the baseline year, with the **top 10** Chinese EV models introduced into the market as the entrant group. Panel (a) plots the aggregated pass-through rates across a range of tariff levels. For Chinese Entrant EVs (red solid line with circles), the pass-through rate measures the fraction of the tariff-induced increase in per-vehicle tariff payments that is reflected in consumer prices. Specifically, because the tariff is ad valorem, we define pass-through as $\Delta p/\Delta T$, where ΔT denotes the simulated change in tariff revenue per vehicle rather than the change in the tariff rate itself. For US-Branded EVs (blue dashed line with squares), the pass-through rate measures the fraction of the recycling-based domestic subsidy that is passed through to consumers in the form of price reductions, defined symmetrically as $-\Delta p/\Delta S$, where ΔS denotes the change in per-vehicle subsidy expenditure. Because the domestic subsidy is modeled as a per-unit subsidy rather than an ad valorem subsidy, this definition coincides with the standard per-dollar subsidy pass-through measure. The horizontal dotted line indicates a pass-through rate of unity. Panel (b) illustrates the corresponding changes in average EV prices ($1,000) for the two groups. The red solid line tracks the average price of Chinese Entrant EVs as the tariff rate increases, while the blue dashed line tracks the average price of US-Branded EVs as they receive the recycled subsidy.

Figure 9: Impacts of Policy on Pricing, Markup, Curvature, and Market Power



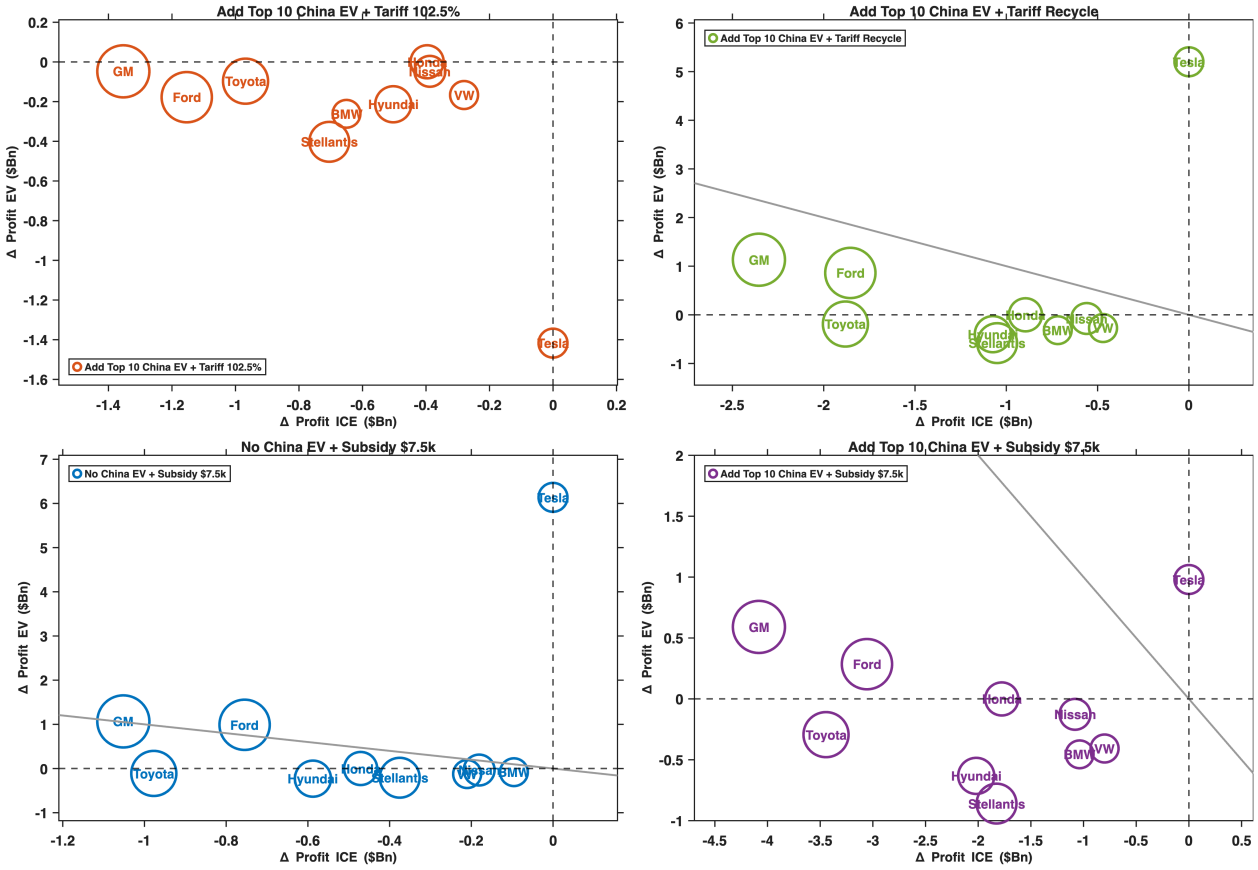
Notes: This figure illustrates the relationship between pricing strategies and demand characteristics for various vehicle models under two scenarios, No Policies (Panels a and c) and the Tariff-recycling Subsidy policy (Panels b and d), using 2023 as the baseline year with the **top 10** Chinese-manufactured EV models introduced as entrants. Each point in the scatter plots represents a specific vehicle model, categorized as Chinese entrant EV (red stars), US incumbent EV - Tesla (dark blue diamonds), US incumbent EV - Other (light blue circles), and US incumbent ICE (grey circles). Panels (a) and (b) plot the markup ($1,000) against the price ($1,000). Panels (c) and (d) plot the demand curvature ($|\sigma_d|$) against the Lerner index (L). The Lerner index is defined as $L_j = (P_j - MC_j)/P_j$, where P_j is the price and MC_j is the marginal cost. Following the framework of Weyl and Fabinger (2013), the demand curvature is defined as $|\sigma_d| = |(s_j \cdot \frac{\partial^2 s_j}{\partial P_j^2})/(\frac{\partial s_j}{\partial P_j})^2|$, which captures the non-linearity of the market share response to price changes.

Figure 10: Optimal Policy Mix and Welfare Contour



Notes: This figure illustrates the simulated changes in social welfare (Δ Welfare) relative to the 2023 status quo across a two-dimensional policy space, following the introduction of the **top 10** Chinese-manufactured EV models. The horizontal axis represents the tariff rate on Chinese EVs, while the vertical axis represents the per-unit subsidy provided to domestic-firm EVs. The heatmap and associated color bar indicate the magnitude of welfare gains in $billions. The gold star identifies the global policy mix that maximizes total welfare (tariff = 22.5%, subsidy = $8.4k). The blue solid line represents the tariff-recycling subsidy path, where all tariff revenues are redistributed as domestic subsidies, with the blue circle marking the optimal point along this constraint (tariff = 25.0%, subsidy = $7.47k). The grey 'x' markers denote the optimal points under single-policy regimes: only subsidy at $9.6k and only tariff at 27.5%. The red dashed and dotted lines represent the best response functions: the optimal subsidy for a given tariff level and the optimal tariff for a given subsidy level, respectively.

Figure 11: Changes in Profits after Chinese EV Entry under Alternative Policy Scenarios



Notes: This figure illustrates the change in profits for the **top 10** EV models (ranked by baseline market share) under four counterfactual policies relative to the 2023 status quo: Add China EV + 102.5% Tariff (top left), Add China + tariff recycle (top right), No China EV + $7,500 Subsidy (bottom left), and Add China EV + $7,500 Subsidy (bottom right). The horizontal axis denotes the change in profits from ICE vehicles, while the vertical axis denotes the change in profits from EV, in $ billions. Bubble sizes are proportional to each model's total profit in the baseline scenario. In the Tariff Recycle and Subsidy panels, the grey diagonal solid line represents the zero-sum boundary for total profit; points located above this line represent a net increase in total profits.

Table 1: Demand Estimation Results

	(1) OLS		(2) IV		(3) RC		(4) RC	
Parameter	Coef	SE	Coef	SE	Coef	SE	Coef	SE
Panel A: Linear parameters								
Price ($\bar{\alpha}$)	-0.013	0.001	-0.093	0.004	-0.033	0.004	0.009	0.005
1(Home brand)	0.224	0.025	0.169	0.029	0.041	0.034	0.111	0.034
log(Horsepower)	-0.123	0.037	2.589	0.125	2.584	0.153	0.993	0.210
Fuel economy	-0.055	0.003	0.009	0.004	0.020	0.006	0.013	0.012
log(Driving Range) $\times$ EV	1.352	0.051	1.172	0.059	2.450	0.039	2.112	0.191
log(Footprint)	0.277	0.023	0.755	0.033	0.893	0.046	0.485	0.054
Panel B: Non-linear parameters								
σ, Constant					0.336	0.128	0.747	0.128
σ, EV					2.490	0.094	2.485	0.109
σ, log(Footprint)					0.186	0.010	0.233	0.012
σ, Brand, CHN					0.228	0.444	0.252	0.438
σ, Brand, US+CA					1.349	0.117	1.568	0.126
σ, Brand, EU: larger markets					0.233	1.022	0.304	0.741
σ, Brand, EU: smaller markets					1.709	0.265	0.387	0.089
α_1, CHN					1.849	0.095	1.992	0.120
α_1, JP/SP/FR/DE					2.405	0.268	2.911	0.333
α_1, UK/NL/AT/SE					0.800	0.061	0.998	0.066
α_1, CA/NO/US/CH					0.728	0.052	1.107	0.074
σ, Price					0.084	0.005	0.103	0.006
Country-Year FE	Yes		Yes		Yes		Yes	
Body Type FE	Yes		Yes		Yes		Yes	
Segment FE	Yes		Yes		Yes		Yes	
Fuel Type FE	Yes		Yes		Yes		Yes	
Brand FE	Yes		Yes		Yes		Yes	
Country-Year-EV FE	No		No		No		Yes	
Brand-EV FE	No		No		No		Yes	

Notes: The demand estimation is based on annual sales by vehicle model by country in the 13 EV major countries of the global automobile market from 2004 to 2020. The number of observations is 65,574 . All regressions include country, year, body type, segment, fuel type, and brand fixed effects. Column (1) reports results for the OLS logit regressions; Column (2) reports 2SLS IV estimation. The first set of instruments includes the number of rival brands, the count of models of the own brand and rival brands, the count of models of the own brand in other markets, and the average model characteristics of the own and rival brands. The second set of instruments includes battery supplier dummies that interacted with battery capacity, as well as three IVs based on vehicle attributes. The third set of instruments includes the number of products in the same predefined market scope that are within one standard deviation of an attribute. Column (3) is a random coefficient multinomial logit model and is estimated using simulated GMM with IVs and micro-moments. Column (4) is a random coefficient multinomial logit model with two additional fixed effects: country-by-year-by-EV and brand-by-EV fixed effects. The price coefficient α_i is specified as $\bar{\alpha} + \alpha_{1,M}/y_{i,M} + \sigma_p \nu_{i,p}$, where y_i is consumer income and $\nu_{i,p}$ is the unobserved preference shock (i.i.d. log-normal draws). The standard errors are clustered at the country by brand level.

Table 2: Welfare Effects under Optimal Policy Mixes: Adding **Top 10** Chinese EVs to the US Market, Year = 2023

	(1)	(2)	(3)	(4)	(5)	(6)
	Ban	**Ban**	**Add top 10 China manufactured EV + Optimal designs**			
		Subsidy	*Tariff Only*	*Subsidy Only*	*Both*	*Recycling*
Tariff/Subsidy		\$7.5k	27.5% / \$0.00k	0.0%/\$9.60k	22.5% / \$8.40k	25.0% / \$7.62k
Panel (a) Effects on EV adoption						
Weighted Price: ICE (\$1,000)	42.62	42.85	42.51	43.05	42.81	42.75
Weighted Price: Non-Chinese EV (\$1,000)	53.18	43.14	52.44	37.87	39.75	40.99
Weighted Price: Chinese EV (\$1,000)	0.00	0.00	38.99	32.85	37.62	38.17
Total Sales (1,000)	15,327	15,508	15,646	16,079	15,882	15,840
Total EV Sales (1,000)	1,380	2,029	2,513	3,790	3,241	3,119
EV Share (%)	9.00	13.08	16.06	23.57	20.41	19.69
Chinese EV % of total EV	0.00	0.00	58.78	51.60	44.50	45.19
Profit, CHN EV (\$Bn)	0.00	0.00	17.01	25.95	16.73	16.16
Panel (b) Effects on US Welfare						
△ Welfare (\$Bn)		5.72	41.09	43.26	45.72	45.62
△ Consumer Surplus (\$Bn)		8.71	34.24	53.67	45.01	42.91
△ Government Revenue (\$Bn)		-11.82	11.69	-14.77	-3.01	
△ Profits, All US firms (\$Bn)		6.73	-8.49	-3.10	-2.15	-2.81
△ Profit, US EV		8.53	-3.78	4.52	4.33	3.41
△ Profit, US ICE		-1.81	-4.70	-7.62	-6.48	-6.22
△ Env. Benefits (\$Bn)		2.10	3.66	7.46	5.87	5.51

Notes: This table reports the market and welfare effects of introducing the **top 10** Chinese EV models into the US market under optimal policy designs. Column (1) reports the status quo, in which Chinese EVs are banned from the US market. Column (2) maintains the ban while providing a subsidy to domestically manufactured EVs. Column (3) reports the optimal tariff, and Column (4) reports the optimal subsidy. Column (5) reports the globally optimal policy mix, allowing both tariffs and subsidies. Column (6) reports the optimal tariff-recycling subsidy, in which the tariff and subsidy are jointly chosen under a balanced-budget constraint. The counterfactual is based on the year 2023. All monetary values are normalized to 2023 USD. The shipment cost is calibrated at \$2,750, and additional distribution and marketing costs are \$1,402. The profit generated from distribution and market services is assumed to pertain to US domestic firms. All average numbers are calculated as sales-weighted averages across models.

Table 3: Welfare and Market Impacts of Chinese EV Entry under Alternative Policy Scenarios

	(1)	(2)	(3)	(4)	(5)	(6)
	Add top 10 China manufactured EV + Policy-relevant scenerios					
	Baseline Tariff	*Punitive Tariff*	*Prohibitive Tariff*	*Tariff Recycle*	*Quota*	*Subsidy*
Subsidy/Tariff/Quota	2.5%	27.5%	102.5%	102.5%	0.5 Mn unit	$7,500
Panel (a) Effects on EV adoption						
Weighted Price: ICE ($1,000)	42.72	42.51	42.39	42.68	42.41	42.93
Weighted Price: Non-Chinese EV ($1,000)	53.59	52.44	51.79	40.81	51.91	41.53
Weighted Price: Chinese EV ($1,000)	33.95	38.99	56.72	57.16	44.72	32.94
Total Sales (1,000)	15,798	15,646	15,435	15,639	15,540	15,993
Total EV Sales (1,000)	2,990	2,513	1,786	2,475	2,160	3,562
EV Share (%)	18.92	16.06	11.57	15.83	13.90	22.27
Chinese EV % of total EV	69.00	58.78	30.56	19.34	47.83	56.61
Profit, CHN EV ($Bn)	27.92	17.01	5.49	4.94	10.94	26.91
Panel (b) Effects on US Welfare						
△ Welfare ($Bn)	37.73	41.09	30.89	34.77	38.81	42.78
△ Consumer Surplus ($Bn)	41.19	34.24	19.45	28.15	28.08	50.66
△ Government Revenue ($Bn)	1.61	11.69	14.48	0.00	15.02	-9.30
△ Profits, All US firms ($Bn)	-10.18	-8.49	-4.38	3.10	-6.84	-5.40
△ Profit, US EV	-4.54	-3.78	-1.88	7.31	-3.03	1.73
△ Profit, US ICE	-5.64	-4.70	-2.51	-4.21	-3.80	-7.14
△ Env. Benefits ($Bn)	5.12	3.66	1.34	3.52	2.55	6.82
△ Mfg Jobs (Thousands)	-86.91	-62.80	-22.68	-11.25	-44.01	-76.66

Notes: This table reports the market and welfare effects of introducing the **top 10** Chinese EV models into the US market under a set of real-world and hypothetical policy environments. Column (1) applies the baseline 2.5% WTO most-favored-nation (MFN) tariff. Column (2) mimics the 2018 Trump administration's Section 301 action, which imposed an additional 25% punitive tariff. Column (3) reflects the May 2024 Biden administration Section 301 update, raising the total tariff to 102.5%. Column (4) considers a hypothetical policy in which revenue from the 102.5% tariff is earmarked to fund domestic EV subsidies. Column (5) simulates a 500,000-unit quota, conceptually similar to a Canada-China bilateral EV agreement. Column (6) models a policy similar to the $7,500 consumer tax credit under the Inflation Reduction Act, strictly limiting eligibility to domestic EVs. The baseline year is 2023. All monetary values are normalized to 2023 USD. The shipment cost is calibrated at $2,750, and additional distribution and marketing costs are $1,402. The profit generated from all average numbers, distribution, and market services is assumed to pertain to US domestic firms. All average numbers are calculated as sales-weighted averages across models. For Column (4), the budget balance EV subsidy that cycles back to domestic EV makers is about $8,139.

Table 4: Distributional Impacts of Chinese EV Entry under Alternative Policy Scenarios

	(1)	(2)	(3)	(4)	(5)	(6)
	Add top 10 China manufactured EV + Policy-relevant scenerios					
	Baseline Tariff	*Punitive Tariff*	*Prohibitive Tariff*	*Tariff Recycle*	*Quota*	*Subsidy*
Subsidy/Tariff/Quota	2.5%	27.5%	102.5%	102.5%	0.5 Mn unit	$7,500
Panel (a) Effects on EV Share by Income Quantile						
EV Share (%) Q1	19.56	15.62	9.18	13.68	12.46	22.71
EV Share (%) Q2	14.62	12.41	9.18	13.23	10.85	18.29
EV Share (%) Q3	19.45	17.15	13.74	17.82	15.54	22.53
EV Share (%) Q4	22.05	19.06	14.19	18.59	16.76	25.57
Panel (b) Effects on Consumer Surplus by Income Quantile						
△ Consumer Surplus ($Bn) Q1	8.71	6.36	2.14	4.06	4.45	10.62
△ Consumer Surplus ($Bn) Q2	5.59	4.57	2.39	4.27	3.66	7.77
△ Consumer Surplus ($Bn) Q3	14.63	12.85	8.39	10.56	11.14	17.02
△ Consumer Surplus ($Bn) Q4	12.27	10.45	6.53	9.25	8.83	15.25

Notes: This table report the distributional impact of introducing the **top 10** Chinese EV models into the US market under a set of real-world and hypothetical policy environments. Column (1) applies the baseline 2.5% WTO most-favored-nation (MFN) tariff. Column (2) mimics the 2018 Trump administration's Section 301 action, which imposed an additional 25% punitive tariff. Column (3) reflects the May 2024 Biden administration Section 301 update, raising the total tariff to 102.5%. Column (4) considers a hypothetical policy in which revenue from the 102.5% tariff is earmarked to fund domestic EV subsidies. Column (5) simulates a 500,000-unit quota, conceptually similar to a Canada-China bilateral EV agreement. Column (6) models a policy similar to the $7,500 consumer tax credit under the Inflation Reduction Act, strictly limiting eligibility to domestic EVs. The baseline year is 2023. All monetary values are normalized to 2023 USD. The shipment cost is calibrated at $2,750, and additional distribution and marketing costs are $1,402. The profit generated from all average numbers, distribution, and market services is assumed to pertain to US domestic firms. All average numbers are calculated as sales-weighted averages across models. For Column (4), the budget balance EV subsidy that cycles back to domestic EV makers is about $8,139. Q1 to Q4 are income quantiles, where Q4 represents the wealthiest consumers.

Online Appendix

From Trade War to Green Transition: Optimal Electric Vehicle Tariffs with Revenue-Funded Subsidies

Panle Jia Barwick Jack Collison Shanjun Li Yucheng Wang

A Additional Theoretical Results

Proposition 1. *The optimal tariff τ is positive if and only if the gains from diverting demand towards domestic goods at existing markups plus direct fiscal revenue exceed consumer surplus loss from higher prices. There are four scenarios that favor this condition:*

(i) High domestic markups $(P_j - C_j)$

(ii) Little differentiation between domestic and imported goods

(iii) Many domestic goods relative to imports, i.e., $|J_d|/|J_f|$ is large

(iv) Sufficiently incomplete tariff passthrough, i.e., demand that is not too convex

Proof. Set externalities $\phi = 0$ and fix σ for simplicity. Rearranging the first-order condition for τ:

$$\tau = \frac{\overbrace{\sum_{j\in J}\left[-\frac{\partial \tilde{P}_j}{\partial \tau}Q_j\right]}^{(-)} + \overbrace{\sum_{j\in J_d}\left[(P_j - C_j)\frac{dQ_j}{d\tau} + \frac{\partial P_j}{\partial \tau}Q_j\right]}^{(+)} + \lambda \overbrace{\sum_{j\in J_f}\left[P_j Q_j\right]}^{(+)} - \lambda \overbrace{\sum_{j\in J_d}\left[\sigma \frac{dQ_j}{d\tau}\right]}^{(+)}}{-\lambda \sum_{j\in J_f}\left[\underbrace{\frac{\partial P_j}{\partial \tau}Q_j}_{(\pm)} + \underbrace{P_j \frac{dQ_j}{d\tau}}_{(-)}\right]}$$

Numerator. The numerator balances: (a) consumer surplus loss from higher prices under tariffs; (b) domestic diversion gains from demand shifting towards domestic goods, which scale with product differentiation and grow wider when $|J_d|/|J_f|$ is large, i.e., the base over which diversion aggregates expands while the number of goods bearing the brunt of the consumer cost shrinks; and (c) tariff revenues from imports net of subsidy expenditures. Conditions (i)-(iv) enumerated in the proposition each strengthen channel (b) or weaken channel (a), and can make the numerator positive.

Denominator. The denominator is $-\lambda$ times the marginal change in aggregate pre-tariff import spending withe respect to τ, i.e., the curvature of the Laffer curve. Its sign is governed by tariff passthrough, which hinges on the shape of demand. More-than-complete passthrough implies imports raise pre-tariff prices whereas incomplete passthrough implies imports lower pre-tariff prices. Passthrough strongly depends on the curvature of demand and the relative numbers of imports to domestic goods in Equation (2). These can push passthrough toward or beyond unity.

Case 1: The denominator is positive, i.e., there is sufficiently low passthrough of tariffs by imports. The optimal tariff is positive if and only if the numerator is positive: diversion gains at existing markups plus government revenue exceed consumer welfare loss form higher prices. This is a natural case for the social planner to set positive tariffs.

Case 2: The denominator is negative, i.e., there is sufficiently more-than-complete passthrough by imports. The sign condition reverses. The optimal tariff is positive if and only if the numerator is negative. That is, consumer surplus losses exceed diversion and fiscal gains. Intuitively, if this is the case, it must be that the government can extract sufficiently high marginal revenue from imports by raising tariffs, even if it's at the cost of consumers, because import spending continues to rise with τ and government revenue returns more than compensate. There must be limited diversion, e.g., inelastic demand and high product differentiation, which generates more-than-complete passthrough in the first place.

Discussion There is also a case for import subsidies, i.e., $\tau < 0$. When the denominator is negative (sufficiently incomplete passthrough of tariffs) and consumer surplus losses are outweighed by the gains in domestic profits and fiscal benefits (positive numerator), the tariff may be negative. Finally, though omitted from the equation above, externalities shift the optimal tariff in the direction of Pigouvian correction. If imported goods generate negative externalities ($e(x_j) < 0$ for imports), restricting imports carries additional social value, raising the optimal tariff. Conversely, positive externalities from imports, such as environmental externalities from electric vehicles, lower the optimal tariff. The net direction depends on whether the externality-weighted sum is negative or positive.

□

Proposition 2. *The optimal subsidy is positive when consumer surplus gains from lower domestic prices and increases in domestic profits outweigh the fiscal costs of reduced tariff revenues due to diversion away from imports and direct subsidy expenditures. The key tension is that product differentiation that amplifies consumer surplus gains also accelerates the erosion of tariff revenue.*

Proof. Set externalities $\phi = 0$ and fix τ for simplicity. Rearranging the first-order condition for σ:

$$\sigma = \frac{\overbrace{\sum_{j\in J}\left[-\frac{\partial \tilde{P}_j}{\partial \sigma}Q_j\right]}^{(+)} + \overbrace{\sum_{j\in J_d}\left[(P_j - C_j)\frac{dQ_j}{d\sigma} + \frac{\partial P_j}{\partial \sigma}Q_j\right]}^{(\pm)} + \lambda \overbrace{\sum_{j\in J_f}\left[\tau\frac{\partial P_j}{\partial \sigma}Q_j + \tau P_j\frac{dQ_j}{d\sigma}\right]}^{(-)} - \lambda \overbrace{\sum_{j\in J_d}\left[Q_j\right]}^{(+)}}{\lambda \underbrace{\sum_{j\in J_d}\left[\frac{dQ_j}{d\sigma}\right]}_{(+)}}$$

Denominator. Because a subsidy reduces domestic marginal cost, it unambiguously expands domestic output ($dQ_j/d\sigma > 0$ for $j \in J_d$). The denominator is therefore unambiguously positive. This is different from the optimal tariff, where the shape of the Laffer curve determined the sign of the denominator. In the case of the subsidy, the optimal policy is entirely determined by the sign of the numerator.

Numerator. The numerator balances: (a) gains in consumer surplus due to lower prices (direct passthrough of own subsidies and through strategic complementarity), pushing σ higher; (b) ambiguous domestic profit effects (volume expansion versus subsidy passthrough that lowers markups, depending on demand curvature); (c) tariff revenue erosion due to diversion to away from imports to domestic goods; and (d) increasing total government expenditures on subsidies through volume expansions. The optimal subsidy is positive if and only if the gains from (a) (and potentially from (b)) outweigh the losses from (c) and (d) (and potentially (b)).

Discussion The same product differentiation channel that strengthens consumer surplus gains in channel (a) amplify tariff revenue erosion in channel (c). When the government revenue channel is strong enough, the planner may even set $\sigma < 0$ to restore revenue if the gains outweigh losses in consumer surplus. And, as above, externalities move the optimal subsidy in the direction of the Pigouvian correction.

□

Corollary 1. *When tariff revenue is recycled into domestic subsidies, the revenue-constrained optimal tariff τ^* differs from its unconstrained counterpart τ_u^* in a manner that depends on the shadow value of public funds λ and the passthrough regime of Proposition 1:*

	Case 1	***Case 2***
$\lambda \in (0,1)$	$\tau^* > \tau_u^*$	$\tau^* < \tau_u^*$
$\lambda > 1$	$\tau^* < \tau_u^*$	$\tau^* > \tau_u^*$
$\lambda = 1$	$\tau^* = \tau_u^*$	$\tau^* = \tau_u^*$

Case 1 is sufficiently incomplete passthrough and Case 2 is sufficiently more-than-complete passthrough. In all four cases, the magnitude of the deviation from the unconstrained planner's solution scales with $|\lambda - 1|$.

Proof. Recall expression for τ^* in Proposition 1. The revenue recycling constraint links σ to tariff revenue, and the shadow value of public funds λ weights the fiscal terms in the denominator. When $\lambda = 1$, the shadow value of expanding the budget by one unit equals one unit of welfare, so the budget constraint is neither tight nor slack. The constrained and unconstrained optima are identical (third row of the table).

When $\lambda \in (0,1)$, the budget constraint is relatively slack and the planner places a welfare premium on fiscal revenue of less than one. The fiscal terms in the denominator receive less weight, reducing the marginal fiscal cost of raising τ. The effect on τ^* depends on the sign of the denominator: in Case 1 (positive denominator, sufficiently incomplete passthrough), the reduced fiscal weight translates into a higher optimal tariff, because the planner can afford to use tariffs more aggressively without being constrained by revenue concerns. Furthermore, this connects with attenuated losses in consumer surplus due to incomplete passthrough. In Case 2 (negative denominator, sufficiently more-than-complete passthrough), the direction reverses, yielding a lower tariff, which is intuitive because consumer surplus losses are enhanced by high passthrough (first row of the table).

When $\lambda > 1$, the budget constraint is tight and each dollar of fiscal revenue is valuable. The inflated weight on fiscal terms magnifies the marginal fiscal cost of raising the tariff, making the planner more cautious in raising tariffs. Thus, the optimal tariff is lower in Case 1 and higher in Case 2 (second row of the table).

The deviation from the unconstrained planner's solution scales with $1/\lambda$, the shadow value of expanding the budget.

□

Proposition 3. *Tariffs and subsidies are policy complements* ($\frac{d^2W}{d\tau d\sigma} > 0$) *when the profit gain from jointly expanding domestic demand (tariff diversion of demand toward domestic goods and the subsidy increasing the total quantity demanded) outweighs two forces pushing the policies towards*

substitutes ($\frac{d^2W}{d\tau d\sigma} < 0$): (i) the consumer surplus channel, through which tariffs and subsidies move prices in opposite directions, and (ii) the fiscal channel, through which the subsidies erode the import demand base that generates tariff revenue. The policy instruments are complements when products are sufficiently differentiated, and demand is concave, which implies that diversion is large and passthrough of rival cost shocks is small. Conversely, the policy instruments are substitutes when products are close substitutes, and demand is convex, amplifying the consumer surplus and fiscal channels relative to the profit channel.

Proof. The policies instruments are complements when the cross-partial $\frac{d^2W}{d\tau d\sigma} > 0$ and substitutes when $\frac{d^2W}{d\tau d\sigma} < 0$. We differentiate $dW/d\tau$ with respect to σ. The cross-partial then decomposes into three channels:

$$\frac{d^2W}{d\tau d\sigma} = \underbrace{-\sum_{j\in J}\frac{\partial^2\tilde{P}_j}{\partial\tau\,\partial\sigma}Q_j}_{\text{Second-order effects}} - \underbrace{\sum_{j\in J}\frac{\partial Q_j}{\partial\tilde{P}_j}\frac{\partial\tilde{P}_j}{\partial\tau}\frac{\partial\tilde{P}_j}{\partial\sigma}}_{\text{Consumer surplus}} + \underbrace{\sum_{j\in J_d}\left[\frac{\partial P_j}{\partial\tau}\frac{dQ_j}{d\sigma}+\frac{dQ_j}{d\tau}\right]}_{\text{Domestic profits}} + \underbrace{\lambda\left[\sum_{j\in J_f}\left(\frac{\partial P_j}{\partial\sigma}Q_j+P_j\frac{dQ_j}{d\sigma}\right)-\sum_{j\in J_d}\frac{dQ_j}{d\tau}\right]}_{\text{Government revenue}}. \tag{A1}$$

Second-order effects The term $\partial^2\tilde{P}_j/\partial\tau\,\partial\sigma$ measures how the subsidy changes the passthrough of the tariff into consumer prices. The second-order effects channel has an ambiguous sign in general, and cannot be signed without further restrictions on demand.

Consumer surplus The tariff raises all consumer prices ($\partial\tilde{P}_j/\partial\tau > 0$ for all j) while the subsidy lowers them ($\partial\tilde{P}_j/\partial\sigma < 0$ for all j). The product of these is therefore negative for every good. Since demand slopes down ($-\partial Q_j/\partial\tilde{P}_j > 0$), the consumer surplus channel is unambiguously negative, i.e., the two instruments always push consumer prices in opposite directions, which pushes the policies towards being substitutes. The magnitude of this channel scales with the product of the two passthrough terms and thus with both product differentiation and demand curvature.

Domestic profits The domestic profits channel contains two positive terms. First, $\partial P_j/\partial\tau > 0$ for $j \in J_d$ (domestic prices rise through strategic complementarity when the tariff raises import prices) and $dQ_j/d\sigma > 0$ for $j \in J_d$ (the subsidy expands demand for domestic goods), so their product is positive, i.e., the tariff and subsidy support domestic market expansion. Second, $dQ_j/d\tau > 0$ for $j \in J_d$ (the tariff diverts demand toward domestic goods), which increases the base over which the subsidy operates. This channel is therefore unambiguously positive and moves the policies towards complements. As above, the magnitude of this channel scales with the degree of demand diversion and strategic complementarity among domestic firms.

Government revenue The government revenue channel is always negative. The subsidy diverts demand away from imports ($dQ_j/d\sigma < 0$ for $j \in J_f$), shrinking the import demand base that generates tariff revenue and making the term $\sum_{j\in J_f}(\partial P_j/\partial\sigma\, Q_j + P_j\, dQ_j/d\sigma)$ negative. The second term, $-\sum_{j\in J_d} dQ_j/d\tau < 0$, captures a similar effect. The tariff shifts demand toward domestic goods, reducing import quantities and the fiscal return to the tariff. Weighted by $\lambda \geq 0$, this channel is unambiguously negative and pushes the policies towards being substitutes. It strengthens as the fiscal value of tariff revenue (λ) rises.

Sufficient condition for complements Since the second-order effects channel has ambiguous sign, $\frac{d^2W}{d\tau d\sigma} > 0$ cannot be characterized by a necessary and sufficient condition without restrictions on demand curvature. A sufficient condition is that the domestic profit channel dominates the remaining channels:

$$\sum_{j\in J_d}\left[\frac{\partial P_j}{\partial\tau}\frac{dQ_j}{d\sigma}+\frac{dQ_j}{d\tau}\right] > -\sum_{j\in J}\frac{\partial Q_j}{\partial\tilde{P}_j}\frac{\partial\tilde{P}_j}{\partial\tau}\frac{\partial\tilde{P}_j}{\partial\sigma} - \lambda\left[\sum_{j\in J_f}\left(\frac{\partial P_j}{\partial\sigma}Q_j + P_j\frac{dQ_j}{d\sigma}\right) - \sum_{j\in J_d}\frac{dQ_j}{d\tau}\right] + \left|\sum_{j\in J}\frac{\partial^2\tilde{P}_j}{\partial\tau\,\partial\sigma}Q_j\right|. \tag{A2}$$

The right-hand side scales with rival cost passthrough (product differentiation and demand curvature), the shadow value of the the budget (λ), and the magnitude of the second-order effects. Equation (A2) is most likely satisfied when products are sufficiently differentiated, and demand is concave, i.e., diversion effects (left-hand side) are large, rival cost passthrough and second-order terms (right-hand side) are small, and each instrument expands the domain the other is working on rather than shrinking it. Substitutes are favored when products are close substitutes, and demand is convex, amplifying the right-hand side relative to the left.

Limiting cases Under strong product differentiation ($\partial Q_j/\partial\tilde{P}_k \to 0$ for $j \neq k$), rival cost passthrough vanishes, the second-order term vanishes because $\partial P/\partial\sigma \to 0$ for foreign goods, and the consumer surplus channel collapses. The right-hand side of Equation (A2) approaches zero while the left-hand side remains positive, so the sufficient condition holds and the instruments are complements. Under homogeneous goods, the passthrough terms in the consumer surplus channel are maximized, and the second-order term is large, dominating the profit channel and making the instruments substitutes.

□

B Additional Monte Carlo Results

Market Structure Figure D.1 examines how optimal policies vary with N_f/N_d, fixing the BLP demand specification throughout. In the left panel, the optimal tariff τ^*, fixing $\sigma = 0$, is declining

in N_f/N_d both with and without revenue recycling. As N_f grows, losses in consumer surplus are amplified with higher tariffs, yielding a decreasing optimal tariff curve. Strikingly, revenue recycling yields higher optimal tariffs than no revenue recycling when N_f is small, but lower optimal tariffs when N_f is large. When imports are scarce, tariff revenue is limited and revenue recycling channels these modest proceeds into domestic subsidies. The planner thus needs a higher τ to generate enough revenue to fund a meaningful subsidy σ. When there are many imports, tariff revenue is large even at moderate τ, and the recycling subsidy is generous enough that the planner can afford to lower τ.

The optimal subsidy σ^* with $\tau = 0$ is increasing in N_f/N_d (right panel). As the domestic industry faces a larger pool of import competitors, the social return to reducing domestic costs through subsidies increases. Each unit reduction in domestic costs translates to larger market share gains and greater consumer surplus benefits when more substitutes are competing for the same consumers.

Product and Cost Differentiation Figure D.2 varies the import mean utility δ_f relative to the domestic baseline $\delta_d = 1$, tracing out the optimal policies τ^*, σ^* as a function of differentiation. In the left panel, there is no revenue recycling. As δ_f rises, consumers increasingly favor imports, and the planner's optimal response is to increase the tariff because losses in consumer surplus are outstripped by gains in government revenue. At the same time, subsidies become less effective per dollar spent. Domestic products are low quality, so no subsidy can fully close the gap, meaning σ^* declines. Under revenue recycling (right panel), the trend dramatically reverses. With recycling, the planner is forced to recycle tariff revenue into subsidies to low quality domestic goods, so the planner wants to set lower tariffs as the disparity increases.

Figure D.3 repeats the exercise varying domestic marginal cost c_d. At the vertical dashed line, we have $c_d = c_f = 1$ (the baseline). Without recycling (left panel), the trend in the optimal policies depends on the relative cost. When domestic goods are cheaper than imports, subsidies are higher than tariffs, with their optimal levels both declining until the point where $c_d = c_f$, i.e., imports are not differentiated from domestic goods in terms of cost. Intuitively, tariffs are not as useful to divert demand to domestic goods when those goods are already less expensive. After domestic goods become more expensive than imports, the planner starts to prefer tariffs, reverting to the intuition from product differentiation above. Upon introducing revenue recycling (right panel), the planner's solution dramatically reverses. Given that there is low demand for imports because they are more costly with $c_d \to 0$, the planner sets a high tariff. As domestic costs increase, the planner decreases tariffs and uses the increasing revenues (due to higher demand for imports) to finance much larger subsidies.

C Derivations and Formulas

C.1 Price Decision Rules for Exporter with Ad Valorem Tariff.

The profit function for exporter is,

$$\pi_{fm}(s_{fmt}) = \max_{p_{jmt}} \sum_{j \in \mathscr{J}_{fmt}} \left[\left(p_{jmt} - (mc_{jmt} + shipment) \right) q_{jmt}(s_{fmt}, \tilde{p}_{jmt}); \tilde{\mathbf{p}}_{-j,mt} \right] \qquad \forall m \in 1, ..., M \tag{C.1}$$

Where

$$\tilde{p}_{jmt} = p_{jmt} \times (1+\tau) + otherCosts$$

$$\tilde{\mathbf{p}}_{-j,mt} = \mathbf{p}_{-j,mt} \times (1+\tau) + otherCosts$$

The first-order condition of firm f with respect to p_j is we drop subscript mt for simplicity.

$$\sum_{h \in \mathscr{J}_f} \left[p_h - (mc_h + shipment) \right] \frac{\partial q_h}{\partial p_j} (1+\tau) + q_j = 0 \tag{C.2}$$

The equilibrium price vector is defined in matrix notation as:

$$\boldsymbol{p}^* = (\boldsymbol{mc} + shipment) + \triangle^{-1} (1+\tau)\, \boldsymbol{q} \tag{C.3}$$

where $\triangle^{-1} = -\frac{\partial q_h}{\partial p_j}$ if product h and j are produced by same firm and zero otherwise.

The final price that consumers face is

$$\boldsymbol{p}^{consumer} = \left[(\boldsymbol{mc} + shipment) + \triangle^{-1} (1+\tau) \cdot \boldsymbol{q} \right] (1+\tau) + otherCosts - subsidy \tag{C.4}$$

The government revenue from each vehicle is,

$$G^{Rev} = \left[(\boldsymbol{mc} + shipment) + \triangle^{-1} (1+\tau)\, \boldsymbol{q} \right] \cdot \tau - subsidy \tag{C.5}$$

C.2 Pass-through Formula in Differentiated Products Oligopoly

Additive Cost Shocks. Starting from the Bertrand markup equation,

$$\mathbf{p} = \mathbf{mc} + \boldsymbol{\mu}(\mathbf{p}), \tag{C.6}$$

Since the markup vector depends on equilibrium prices, we have

$$d\boldsymbol{\mu} = D_{\mathbf{p}}\boldsymbol{\mu}\, d\mathbf{p}. \tag{C.7}$$

Rearranging gives that the pass-through matrix is

$$\frac{d\mathbf{p}}{d\mathbf{mc}'} = \left[I - D_{\mathbf{p}}\boldsymbol{\mu}\right]^{-1}. \tag{C.8}$$

Using $\boldsymbol{\mu}(\mathbf{p}) = \Delta^{-1}\mathbf{q}(\mathbf{p})$, we obtain

$$D_{\mathbf{p}}\boldsymbol{\mu} = \Delta^{-1}(J+H), \tag{C.9}$$

so that

$$\frac{d\mathbf{p}}{d\mathbf{mc}'} = \left[I - \Delta^{-1}(J+H)\right]^{-1} = (\Delta - J - H)^{-1}\Delta, \tag{C.10}$$

where

$$\Delta_{jk} = -\Omega_{jk}\frac{\partial s_k}{\partial p_j}, \tag{C.11}$$

$$J_{jl} = \frac{\partial s_j}{\partial p_l}, \tag{C.12}$$

$$H_{jl} = \sum_{k=1}^{J} \Omega_{jk}\mu_k \frac{\partial^2 s_k}{\partial p_j \partial p_l}. \tag{C.13}$$

where, j indexes the product whose first-order condition is being considered, k indexes the product whose markup is internalized within that first-order condition, and l indexes the price dimension along which the demand system is differentiated. Δ is the ownership-adjusted matrix of first-order demand derivatives, J is the full Jacobian of demand, and H collects markup-weighted second-order demand derivatives. Ω_{jk} is the ownership matrix, $\mu_k = p_k - c_k$ is the markup of product k, and s_j denotes the market share of product j.

Ad Valorem Tariff. Let

$$M(\boldsymbol{\tau}) \equiv \text{diag}(1+\tau_1, \ldots, 1+\tau_J), \qquad \mathbf{x} = M(\boldsymbol{\tau})^{-1}\mathbf{p},$$

where $\mathbf{x}$ denotes the tax-exclusive price received by firms. The pricing equation can be written as

$$\mathbf{p} = M(\boldsymbol{\tau})\left[\mathbf{mc} + \boldsymbol{\mu}^x(\mathbf{p}, \boldsymbol{\tau})\right], \tag{C.14}$$

where $\boldsymbol{\mu}^x$ is the markup vector in tax-exclusive prices. Define the realized per-vehicle tariff payment vector as

$$\mathbf{T} \equiv \text{diag}(\boldsymbol{\tau})\mathbf{x}. \tag{C.15}$$

Let

$$A \equiv I - M D_{\mathbf{p}} \boldsymbol{\mu}^x, \qquad B \equiv \text{diag}(\mathbf{x}) + M D_{\boldsymbol{\tau}} \boldsymbol{\mu}^x. \tag{C.16}$$

Then the pass-through matrix with respect to tariff payments is

$$\frac{d\mathbf{p}}{d\mathbf{T}'} = A^{-1}B \left[\text{diag}\left(\frac{\mathbf{x}}{1+\boldsymbol{\tau}} \right) + \text{diag}(\boldsymbol{\tau}) M^{-1} A^{-1} B \right]^{-1}. \tag{C.17}$$

Link Between Two Pass-Throughs: A Single-Product Firm Example. We derive the relationship between ad valorem tariff pass-through and unit-specific tariff pass-through in the single-product case, where the mapping can be characterized analytically. Consider the consumer price under an ad valorem tariff τ:

$$p = (1+\tau)(\mu + c),$$

where c is marginal cost and $\mu = \mu(\tau)$ is the tax-exclusive markup, which may vary with the tariff rate τ. This price equation can be written in two equivalent ways. First, using the tariff-revenue decomposition,

$$p = (\mu + c) + \tau(\mu + c) = (\mu + c) + T, \qquad T \equiv \tau(\mu + c),$$

so that

$$\frac{dp}{dT} = \frac{\partial p / \partial \tau}{\partial T / \partial \tau} = \frac{(\mu + c) + (1+\tau)\mu'}{(\mu + c) + \tau \mu'},$$

where $\mu' \equiv d\mu / d\tau$. Second, using the effective-cost decomposition,

$$p = (1+\tau)\mu + (1+\tau)c = \underbrace{(1+\tau)\mu}_{\text{Effective Markup}} + \underbrace{(1+\tau)c}_{\text{Effective Marginal Cost}}.$$

Defining effective marginal cost as

$$\tilde{c} \equiv (1+\tau)c,$$

we obtain

$$\frac{dp}{d\tilde{c}} = \frac{\partial p / \partial \tau}{\partial \tilde{c} / \partial \tau} = \frac{(\mu + c) + (1+\tau)\mu'}{c}.$$

This second object provides the link to a unit-specific tariff. A unit-specific tariff enters the pricing problem as an additive wedge to marginal cost, so its pass-through is naturally measured

by the response of prices to an additive increase in effective cost. In this sense, $dp/d\tilde{c}$ **is the unit-specific tariff is the analogue of pass-through, while** dp/dT **the ad-valorem tariff pass-through with respect to tariff payments**. The ratio between the two is therefore

$$\frac{dp/d\tilde{c}}{dp/dT} = \frac{\mu + c + \tau\mu'}{c}. \tag{C.18}$$

Equation C.18 shows ad valorem and unit-specific tariffs need not generate the same pass-through, because tariff payments under an ad valorem tariff depend not only on marginal cost but also on the level and endogenous response of markup.

For a single-product firm, the Bertrand pricing markup is

$$\mu(p) = -\frac{s(p)}{s_p(p)}.$$

Differentiating with respect to price gives

$$\frac{d\mu}{dp} = -1 + \frac{s\,s_{pp}}{(s_p)^2}.$$

Hence, letting $\mu' \equiv d\mu/d\tau$,

$$\mu' = \left(\frac{s\,s_{pp}}{(s_p)^2} - 1\right)\frac{dp}{d\tau}.$$

Substituting it into Equation C.18, and rearranging yields,

$$\frac{dp/d\tilde{c}}{dp/dT} = \underbrace{\frac{\mu + c}{c}}_{\text{Markup rate}} \cdot \left[1 + (1+\tau)\left(\underbrace{\frac{s\,s_{pp}}{(s_p)^2}}_{\text{Demand curvature}} - 1\right)\varepsilon_{p,\tau}\right]. \tag{C.19}$$

where $\varepsilon_{p,\tau} \equiv \frac{dp}{d\tau}\frac{\tau}{p} > 0$, is the price elasticity with respect to tariff rate.

C.3 Tariff Pass-Through with CES Demand

Consider the standard CES utility aggregator,

$$U = \left(\sum_{j \in \mathscr{J}} q_j^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1,$$

which implies constant-elasticity demand of the form

$$q_j = A p_j^{-\sigma},$$

where A is a demand shifter taken as given by the firm, and σ is the elasticity of substitution across varieties.

Unit-specific Tariff. Now introduce a unit-specific tariff t. Let x denote the producer price received by the firm, so that the consumer price is $p = x + t$. Under CES demand, the firm's problem is

$$\max_x \ \pi = (x-c)A(x+t)^{-\sigma}.$$

The first-order condition is

$$A(x+t)^{-\sigma} - \sigma(x-c)A(x+t)^{-\sigma-1} = 0,$$

which implies

$$x = \frac{t + \sigma c}{\sigma - 1}.$$

Hence the consumer price is

$$p = x + t = \frac{t + \sigma c}{\sigma - 1} + t = \frac{\sigma(c+t)}{\sigma - 1}.$$

Since per-unit tariff payments are $T = t$, tariff pass-through defined as dp/dT is

$$\frac{dp}{dT} = \frac{\sigma}{\sigma - 1} > 1.$$

Thus, under CES demand, a unit-specific tariff is overshifted into consumer prices.

Ad Valorem Tariff. Now introduce an ad valorem tariff at rate τ. Let x_j denote the tax-exclusive price received by the firm. Consumer demand depends on the consumer price $p_j = (1+\tau)x_j$, so

the firm's profit maximization problem becomes

$$\max_{x_j} \ \pi_j = (x_j - c_j)A\left[(1+\tau)x_j\right]^{-\sigma}.$$

The first-order condition is

$$A(1+\tau)^{-\sigma}x_j^{-\sigma} - \sigma(x_j - c_j)A(1+\tau)^{-\sigma}x_j^{-\sigma-1} = 0.$$

Factoring out the common term $A(1+\tau)^{-\sigma}x_j^{-\sigma-1}$ gives

$$x_j - \sigma(x_j - c_j) = 0,$$

which implies

$$x_j = \frac{\sigma}{\sigma - 1}c_j.$$

Thus, the optimal tax-exclusive price also satisfies the same constant-markup rule and does not adjust with the tariff rate. Per-unit tariff payments are given by

$$T_j = \tau x_j.$$

The consumer price is then

$$p_j = x_j + T_j.$$

Since x_j is independent of the tariff rate under CES monopolistic competition, tariff pass-through defined as dp_j/dT_j is exactly

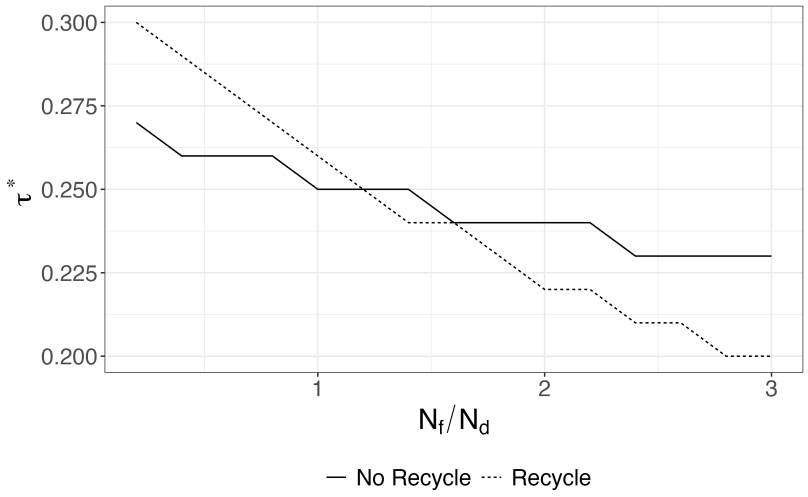
$$\frac{dp_j}{dT_j} = 1.$$

Thus, under CES demand, a one-dollar increase in per-unit tariff payments leads to a one-dollar increase in consumer prices.

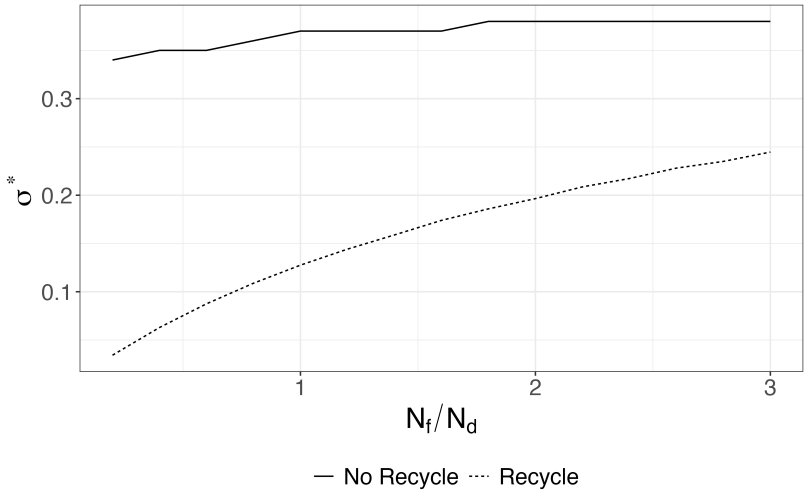
D Appendix Figures

Figure D.1: Optimal Policies by Market Structure

(a) Panel A. τ^* with $\sigma = 0$

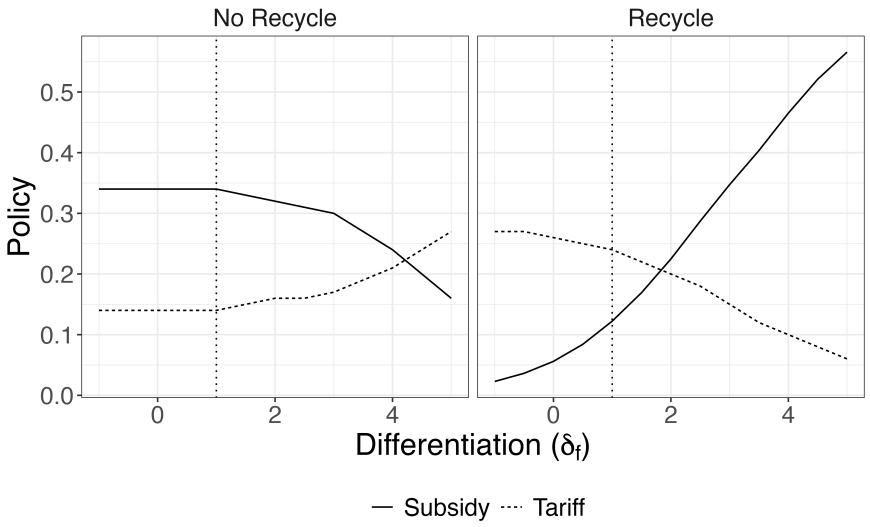


(b) Panel B. σ^* with $\tau = 0$



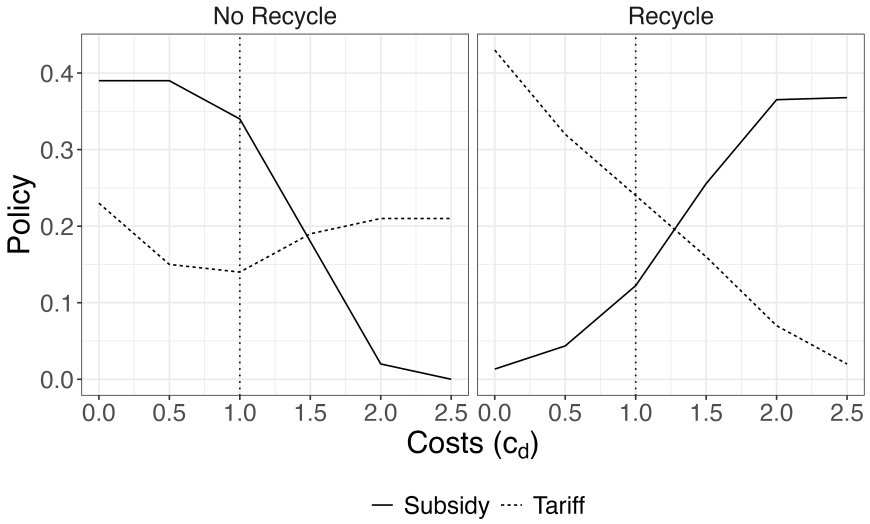
Notes: This figure shows optimal policies over market structure. The left panel shows tariff-only solutions, and the right panel shows subsidy-only solutions. The solid lines are the single policy solutions, and the dotted lines are the revenue recycling solutions. The y-axis is the optimal tariffs/subsidies, and the x-axis represents market structure as the ratio of imports N_f to domestic goods N_d. In the left panel, the planners set tariffs that decrease with the number of imports, and the tariff curve decreases faster for revenue recycling. In the right panel, the planners set subsidies that increase with the number of imports, and the subsidy curve increases faster for revenue recycling.

Figure D.2: Optimal Policies by Product Differentiation



Notes: This figure shows optimal policies over the degree of product differentiation. The left panel is the unconstrained planner, and the right panel is the revenue recycling (balanced-budget) planner. The y-axis is the policy rate (tariff in dotted lines, subsidy in solid lines) and the x-axis is the degree of differentiation, represented by δ_f, the mean non-price utility of the import. A small δ_f means the import is of low quality, and $\delta_f = 1$ is the case where imports and domestic goods have the same quality. The unconstrained planner uses tariffs more and subsidies less as imports become higher quality. Conversely, the balanced-budget planner uses lower tariffs and much higher subsidies with high-quality imports.

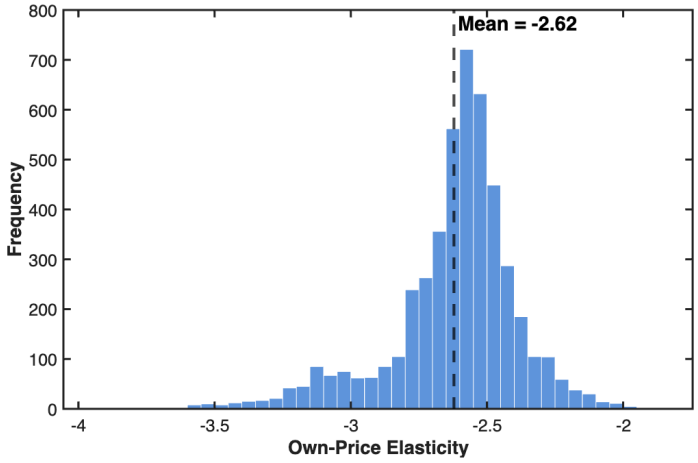
Figure D.3: Optimal Policies by Domestic Marginal Cost



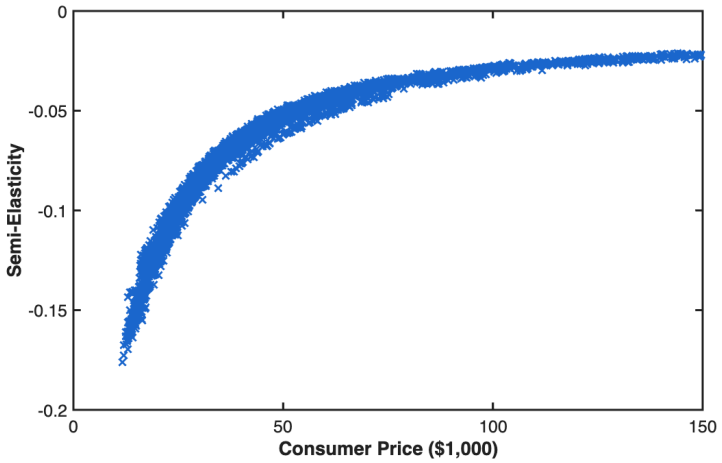
Notes: This figure shows optimal policies over the degree of cost differences. The left panel is the unconstrained planner, and the right panel is the revenue recycling (balanced-budget) planner. The y-axis is the policy rate (tariff in dotted lines, subsidy in solid lines) and the x-axis is the degree of cost differences, represented by c_d, the marginal cost of the domestic good. $c_d = 1$ is the case where imports and domestic goods have the same marginal cost. The unconstrained planner uses tariffs more and subsidies less as domestic goods become higher cost. Conversely, the balanced-budget planner uses lower tariffs and much higher subsidies for high-cost domestic goods.

Figure D.4: Estimated Own-Price Elasticity and Cross-Price Semi-Elasticity

(a) Estimated Own-price Elasticity

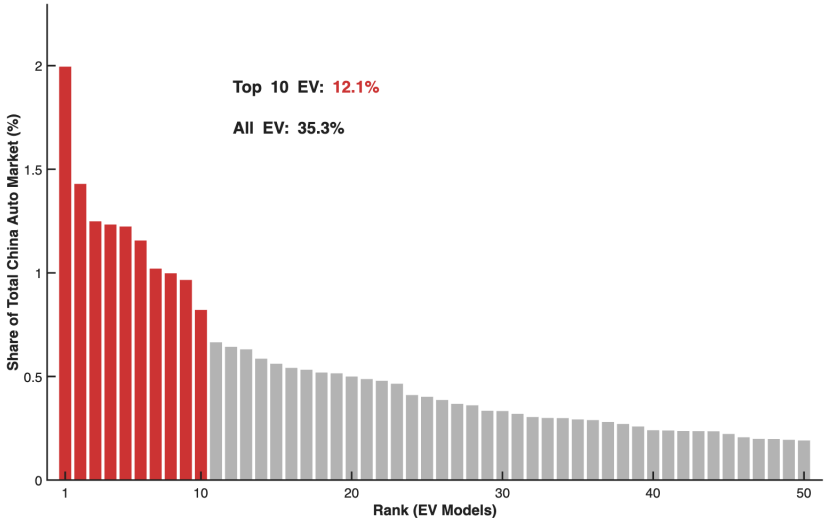


(b) Estimated Semi-Elasticity



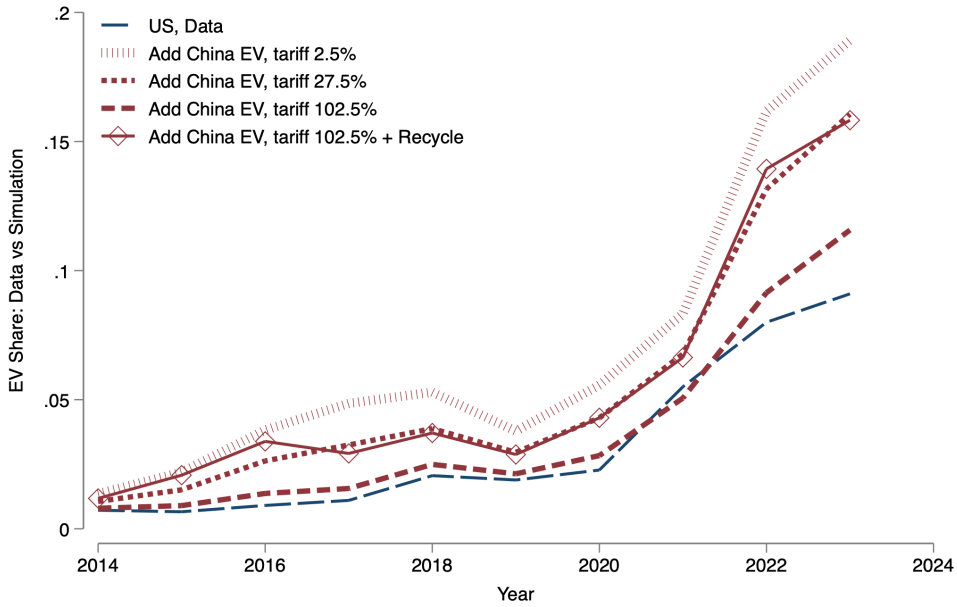
Notes: This figure displays the estimated demand elasticities. Panel (a) displays a histogram of the estimated own-price elasticities for all vehicle models in the sample, where the vertical dashed line indicates a mean elasticity of -2.62. Panel (b) illustrates the cross-price semi-elasticity between automaker groups plotted against the consumer price (measured in $\$1,000$). The semi-elasticity measures the percentage change in the market share of a vehicle model in response to a $\$1,000$ increase in the price of competing models from different automaker groups.

Figure D.5: Market Share Rank of Top Chinese EV Models in the Chinese Market



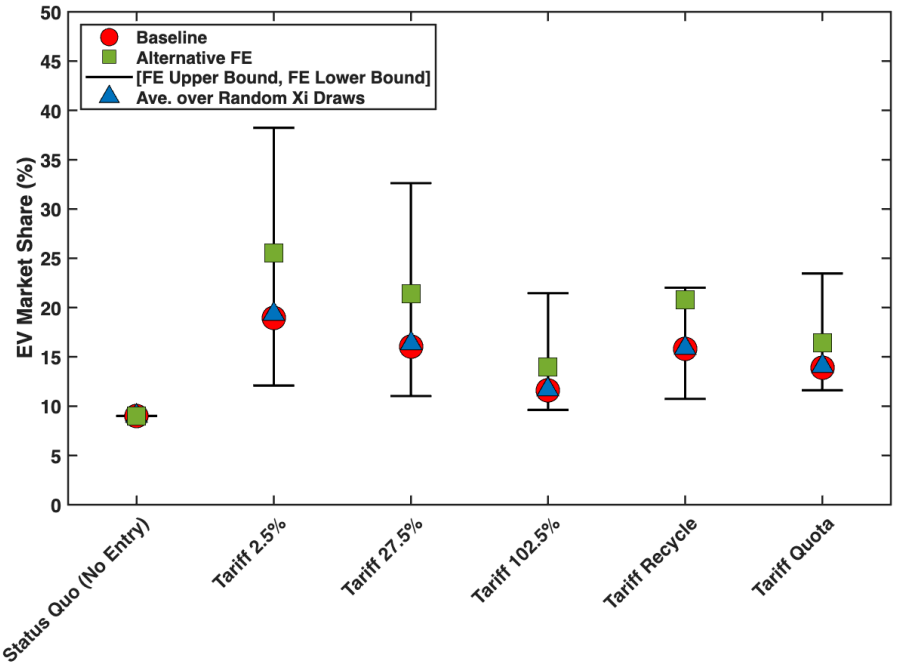
Notes: This figure illustrates the market share distribution of electric vehicle (EV) models in the Chinese domestic market based on 2023 data. The horizontal axis ranks individual EV models by their market share. The vertical axis represents each model's share of the total China auto market. The red bars highlight the **top 10** Chinese-manufactured EV models, which collectively account for 12.1% of the total automotive market. The grey bars represent the subsequent 40 models in the ranking. Collectively, all EV models in the sample represent 35.3% of the total Chinese auto market.

Figure D.6: Simulated EV Market Share in the US Over Time: Add **Top 10** Chinese EVs



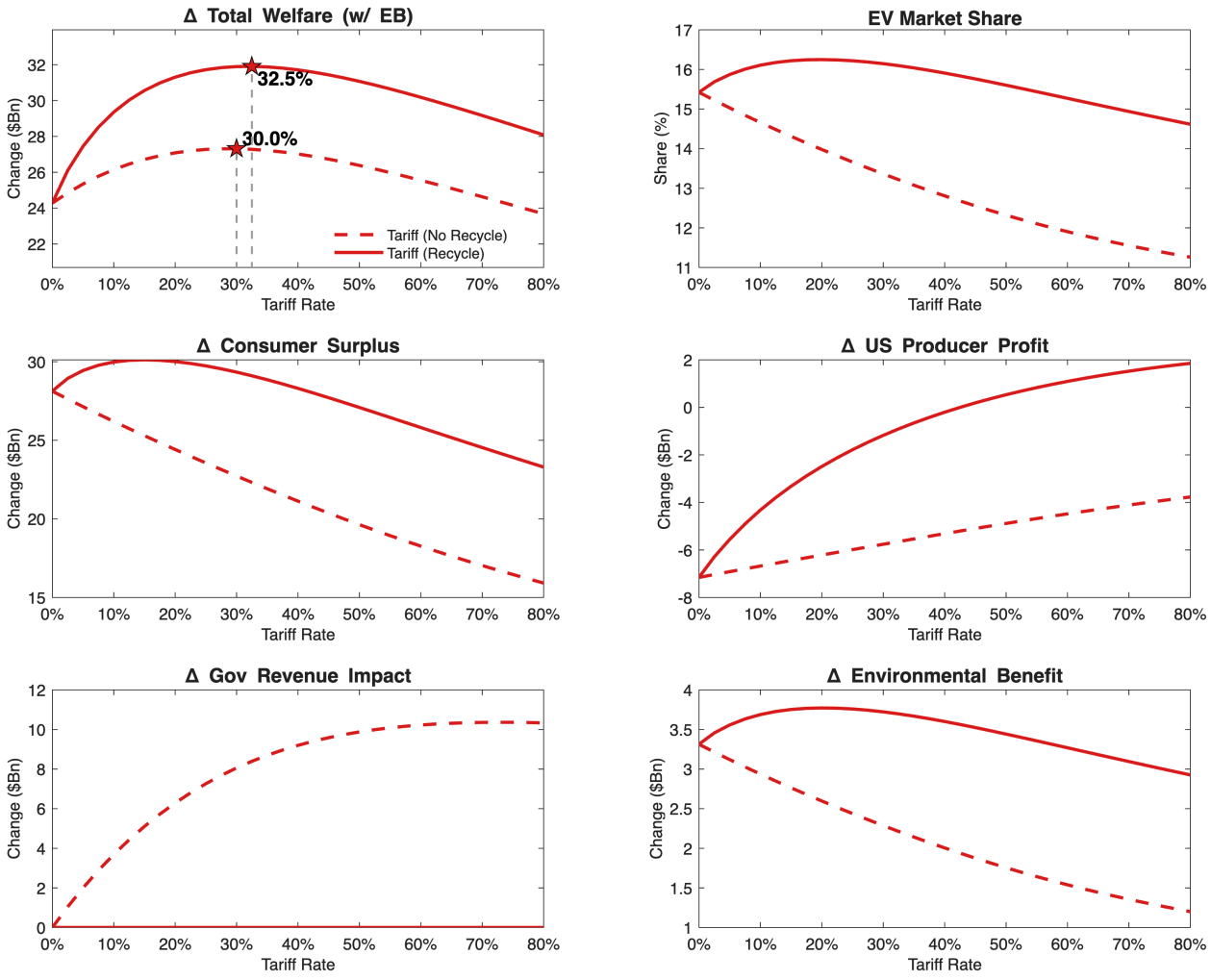
Notes: This figure shows the simulated trend of EV market share in the US market from 2014 to 2023. The blue dashed line represents the actual observed market share of EV in the US during this period. The other curves illustrate simulated scenarios following the introduction of the **top 10** Chinese-manufactured EV models (ranked by their 2023 Chinese market share) under varying policy regimes: a tariff of 2.5% (thin red dotted line), a tariff of 27.5% (thick red dotted line), and a tariff of 102.5% (thick red dashed line). The solid red line represents the scenario with a 102.5% tariff combined with revenue recycling into domestic EV subsidies.

Figure D.7: Robustness Using Alternative Fixed Effects and ξ draws, N. of Chinese EV = **10**



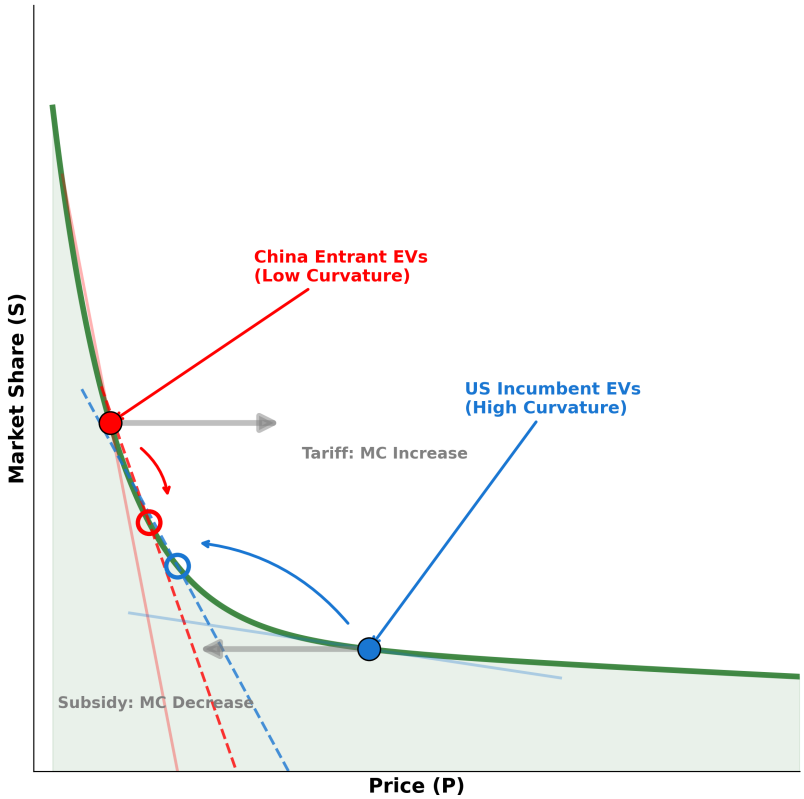
Notes: This figure presents a series of robustness checks for the simulated US EV market share in 2023 across various policy scenarios, serving as a sensitivity analysis for the results presented in Table 3. The simulation results are evaluated against two primary dimensions of uncertainty: the choice of product fixed effects and the unobserved quality (ξ) of the Chinese entrant models. The red circles represent the baseline specification used throughout the paper. The green squares denote the results using alternative fixed effect specifications, with the vertical error bars illustrating the upper and lower bounds of market outcomes constructed by assigning the 75th and 25th percentiles of the observed domestic fixed effects to the entrant models, respectively. The blue triangles show the mean market share calculated from 50 Monte Carlo simulations where the unobserved quality ξ for Chinese entrants is randomly drawn from the empirical distribution of existing models in the US market. The horizontal axis includes scenarios mirroring the policy configurations in the main text.

Figure D.8: Decomposition of Welfare and Relationship with Tariff Rates, N. Chinese EV = **5**



Notes: This figure illustrates the simulated changes in social welfare components and market outcomes relative to the 2023 status quo, following the introduction of the **top 5** Chinese-manufactured EV models into the US market. In each panel, the red solid line represents the scenario with tariff revenue recycling into domestic EV subsidies while the red dashed line represents the scenario without such recycling. The stars in the Total Welfare panel indicate the optimal tariff rates that maximize social welfare under the two respective policy regimes. All monetary values are measured in $billions.

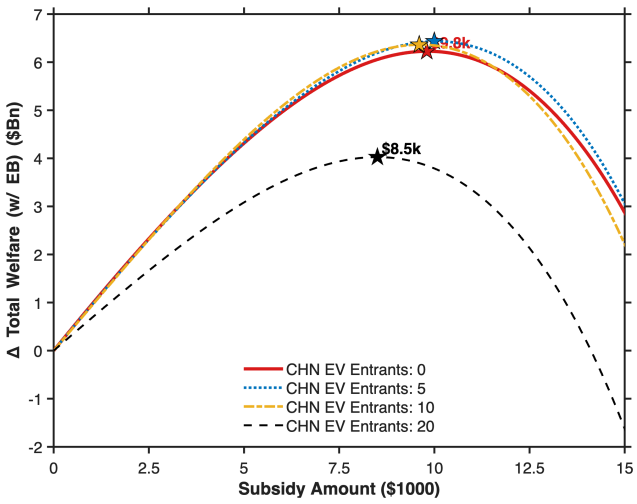
Figure D.9: Illustration the Tariff-recycling Subsidy: Chinese entrant EVs versus US incumbent EVs



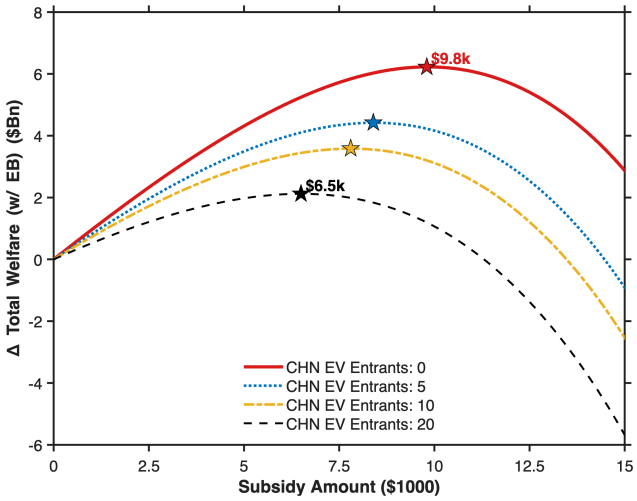
Notes: This figure illustrates the conceptual impacts of the tariff-recycling subsidy on the market equilibrium of Chinese entrant EVs and US incumbent EVs. The green solid curve represents the market demand. The solid red dot represents the initial equilibrium for China entrant EVs, and the solid blue dot represents the initial equilibrium for US incumbent EVs. The solid red and blue lines denote the initial tangents (slopes) at these equilibrium points. The hollow red and blue circles represent the new equilibrium positions following the policy intervention. The dashed red and blue lines denote the new tangents at these new equilibria.

Figure D.10: Optimal Domestic EV Subsidy under Varying Tariff Rates and Market Entry

(a) Tariff = 0%

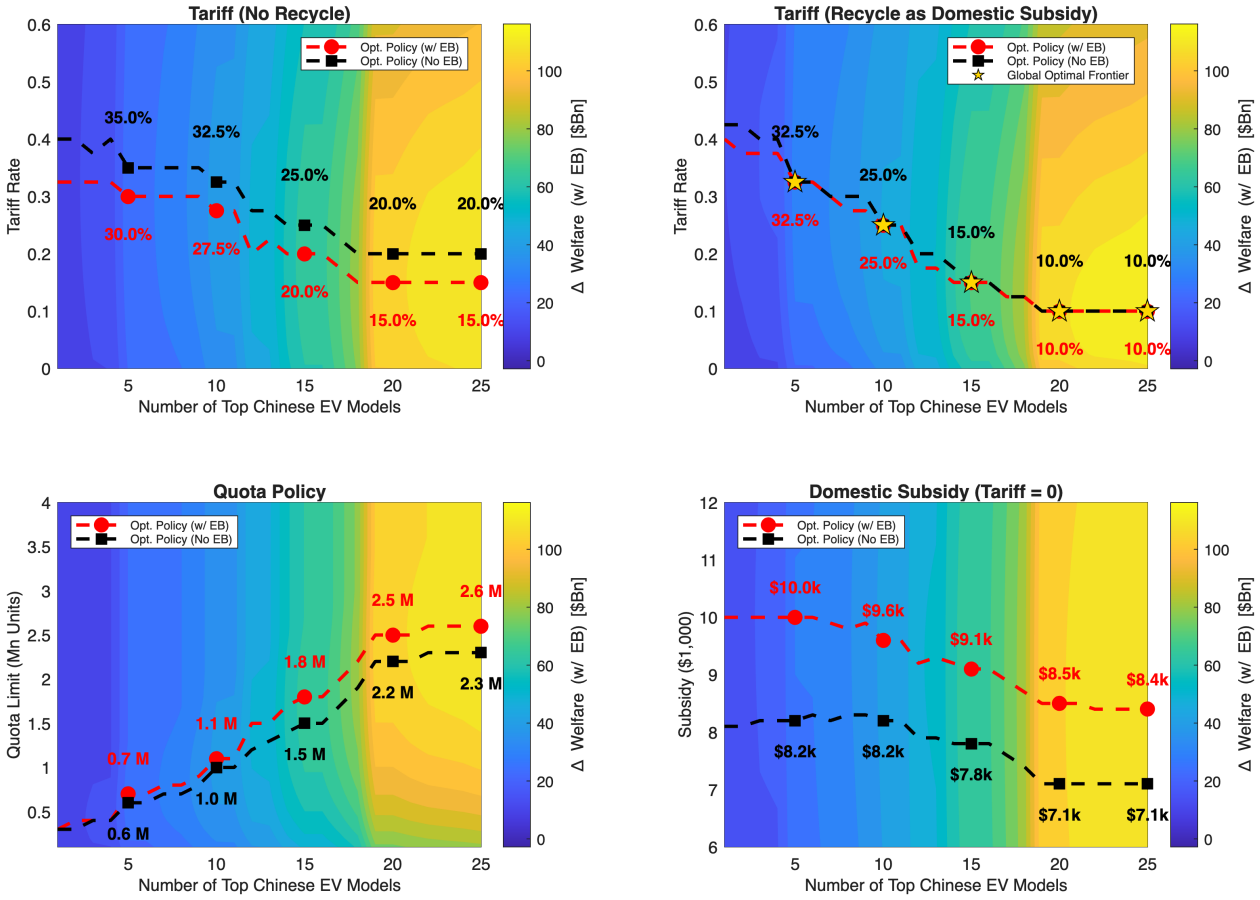


(b) Tariff = 100%



Notes: This figure plots the simulated change in total US welfare (in $billions) as a function of the domestic EV subsidy amount. Panel (a) presents the welfare curves under a 0% tariff rate, while Panel (b) presents the results under a 100 % tariff rate. The different lines correspond to counterfactual scenarios with varying numbers of Chinese EV models entering the US market (0, 5, 10, and 20 entrants). The star markers indicate the optimal subsidy level that maximizes total welfare for each market entry scenario.

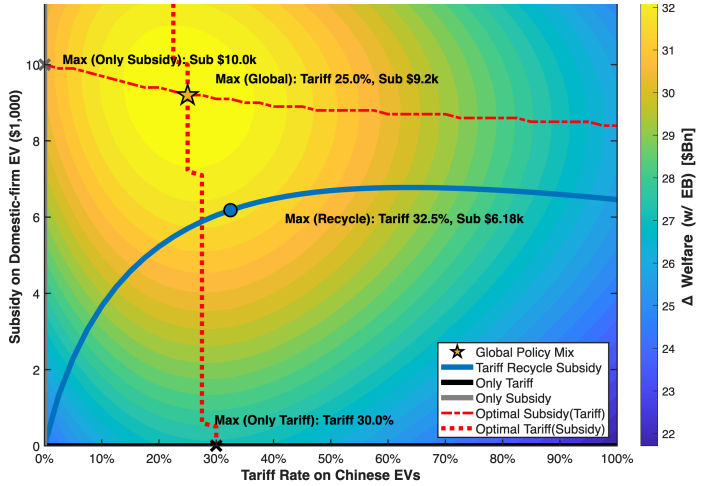
Figure D.11: Optimal Policy Design by Alternative Policy Regimes and Number of Entrants



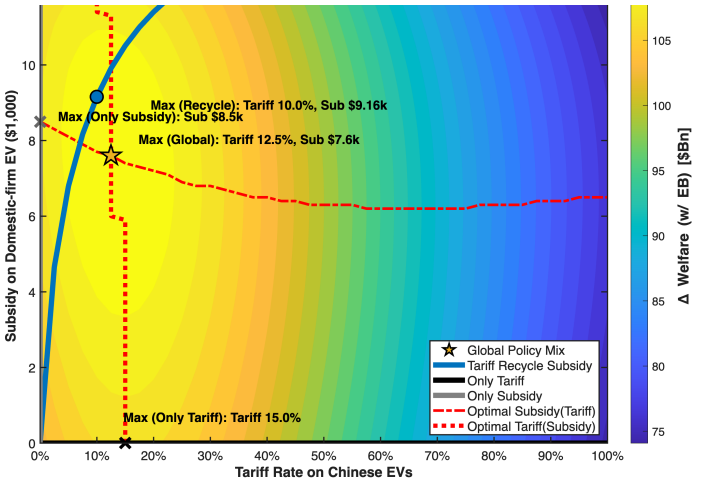
Notes: This figure illustrates the simulated optimal trade policies under varying number of Chinese EV model entry (x-axis) across three scenarios: tariff with no revenue recycling (top left), tariff with revenue recycled as domestic subsidies (top right), and Quota policy (bottom left). The base year is 2023. The y-axis represents the policy value: tariff rate (top panels) or quota in million units (bottom panel). The heatmap indicates the change in total welfare (including environmental benefits) in $billions, relative to the status quo. The red dashed lines trace the optimal policy, while the black dashed lines show the optimal policy with an alternative welfare measure that excludes environmental benefits. The percentage number beside the lines represents the equilibrium EV market share under the corresponding optimal policy. The yellow stars denote the "Global Optimal Frontier," marking the specific policy choice across all three scenarios that yields the highest absolute total welfare for a given number of entrants.

Figure D.12: Optimal Policy Mix and Welfare Contour with Top-5 or 20 Chinese EV models

(a) Top-5 Models



(b) Top-20 Models



Notes: This figure replicates the analysis in Figure 10 using an identical setup, but introduces the top 5 or top 20 Chinese-manufactured EV models as entrants in Panels (a) and (b), respectively, instead of the top 10 models in the baseline. The horizontal axis represents the tariff rate on Chinese EVs, while the vertical axis represents the per-unit subsidy provided to domestic-firm EVs. The horizontal axis represents the tariff rate on Chinese EVs, while the vertical axis represents the per-unit subsidy provided to domestic-firm EVs. The heatmap and associated color bar indicate the magnitude of welfare gains in $billions. The gold star identifies the global policy mix that maximizes total welfare. The blue solid line represents the tariff-recycling subsidy path, with the blue circle marking the optimal point along the balance budget constraint. The grey 'x' markers denote the optimal points under single-policy regimes. The red dashed and dotted lines represent the best response functions: the optimal subsidy for a given tariff level and the optimal tariff for a given subsidy level, respectively.

E Appendix Tables

Table E.1: Summary Statistics

	China		US+CA		EU	
Variables	Mean	SD	Mean	SD	Mean	SD
Panel A. Internal Combustion Engine						
Sales (1,000)	39105.45	60719.32	32958.00	68319.84	5005.03	12249.81
MSRP ($1,000)	31.26	26.21	50.32	25.95	53.14	29.47
Curb Weight (kg)	1481.79	320.71	1780.71	385.40	1559.62	362.01
Footprint (m^2)	8.04	1.39	8.96	1.16	8.15	1.21
Displacement	1.83	0.60	3.17	1.22	1.97	0.75
Horsepower	156.44	61.67	255.22	89.37	162.08	79.37
Fuel Economy (L/100km)	7.59	2.30	11.06	2.63	6.76	1.90
SUV	0.37	0.48	0.39	0.49	0.30	0.46
# of Obs.	7053		9974		38853	
Panel B. EV						
Sales (1,000)	17128.09	41700.62	9423.24	28560.43	1522.19	3195.85
MSRP ($1,000)	32.45	20.20	66.47	32.19	69.07	30.19
Subsidy ($1,000)	3.20	1.33	2.38	2.37	1.70	1.91
Curb Weight (kg)	1675.80	450.78	1938.87	392.96	1896.26	372.99
Footprint (m^2)	7.98	1.55	8.72	1.21	8.42	1.22
Horsepower	186.33	66.10	297.83	162.97	254.20	131.97
Driving Range (km)	317.87	180.02	205.94	189.30	195.19	174.15
Plug-in Hybrid	0.25	0.43	0.45	0.50	0.52	0.50
SUV	0.45	0.50	0.41	0.49	0.48	0.50
# of Obs.	1167		526		5397	

Notes: The sample covers 13 countries with all automobile models sales in between 2004 and 2023. The countries are Austria, Canada, China, France, Germany, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, the UK, and the US All prices and subsidy amounts are normalized in 2023 US dollars ($).

Table E.2: Counterfactual: Add **Top 10** Chinese-manufactured EVs Sold in EU to the US Market, Year = 2023

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ban	**Ban**	**Add Top 10 China manufatured EV**					
		+ Subsidy	*Low*	*Mild*	*Aggressive*	*+ Redistribute*	*+ Quota*	*+ Subsidy*
Subsidy/Tariff/Quota		$7,500	2.5%	27.5%	102.5%	102.5%	0.5 Mn unit	$7,500
Panel (a) Effects on EV adoption								
Weighted Price: ICE ($1,000)	42.62	42.85	42.47	42.48	42.56	42.62	42.47	42.71
Weighted Price: Non-Chinese EV ($1,000)	53.18	43.14	52.04	52.16	52.76	48.60	52.04	41.74
Weighted Price: Chinese EV ($1,000)	0.00	0.00	51.20	62.98	92.44	93.21	53.65	50.86
Total Sales (1,000)	15,327	15,508	15,462	15,402	15,345	15,409	15,445	15,645
Total EV Sales (1,000)	1,380	2,029	1,854	1,636	1,442	1,680	1,794	2,482
EV Share (%)	9.00	13.08	11.99	10.62	9.40	10.90	11.61	15.86
Q1	6.80	11.31	9.22	7.86	6.95	8.59	8.83	13.47
Q2	7.56	11.20	10.19	8.97	7.83	9.10	9.86	13.82
Q3	10.51	14.47	13.75	12.49	11.12	12.59	13.41	17.51
Q4	11.15	15.36	14.80	13.17	11.71	13.32	14.36	18.65
Chinese EV % of total EV	0.00	0.00	34.16	21.16	7.11	5.85	30.85	23.75
Profit, CHN EV ($Bn)	0.00	0.00	10.23	5.48	1.73	1.67	8.81	9.86
Panel (b) Effects on US Welfare: △ Welfare = △ CS + △ Domestic Profit + △ Gov Revenue + △ Env. Benefits								
△ Welfare ($Bn)		5.72	14.34	13.45	7.07	9.94	14.53	19.27
△ Consumer Surplus ($Bn)		8.71	16.04	10.77	3.74	7.20	14.72	24.70
Q1		2.00	1.73	0.90	0.18	0.95	1.50	3.71
Q2		1.80	2.84	1.84	0.53	1.26	2.59	4.68
Q3		2.27	6.02	4.28	1.58	2.48	5.61	8.27
Q4		2.64	5.45	3.75	1.45	2.51	5.02	8.04
△ Government Revenue ($Bn)		-11.82	0.75	4.34	3.87	0.00	2.07	-11.34
△ Profits, All US firms ($Bn)		6.73	-3.97	-2.47	-0.74	1.76	-3.59	2.38
△ Profit, US EV		8.53	-1.91	-1.15	-0.33	2.90	-1.72	6.11
△ Profit, US ICE		-1.81	-2.06	-1.32	-0.41	-1.14	-1.87	-3.73
△ Env. Benefits ($Bn)		2.10	1.53	0.81	0.20	0.98	1.33	3.52
△ Mfg Jobs (Thousands)		7.16	-26.05	-13.49	-3.13	-0.50	-22.54	-16.64

Notes: The counterfactual is based on the year 2023. All monetary values are normalized to 2023 USD. The profit generated from all average numbers, distribution, and market services is assumed to pertain to US domestic firms. All average numbers are calculated as sales-weighted averages across models. For Column (5), the budget balance EV subsidy that cycles back to domestic EV makers is about $3,372. Q1 to Q4 are income quantiles, where Q4 represents the wealthiest consumers.

Table E.3: Top 10 EV Model in China, 2023

Group	Brand	Model	MSRP	Sales
BYD Auto	BYD Auto	QINPLUS	18.90	327371
BYD Auto	BYD Auto	DOLPHIN	18.19	285970
BYD Auto	BYD Auto	YUANPLUS	21.01	282501
BYD Auto	BYD Auto	SEAGULL	11.41	280217
BYD Auto	BYD Auto	SONGPLUS	24.69	264762
SAIC	Wuling	WULINGBINGO	10.90	233735
GAC Group	GAC Aion	AIONY	20.62	228555
GAC Group	GAC Aion	AIONS	19.99	221227
BYD Auto	BYD Auto	SONGPRO	20.28	188007
SAIC	MG	MG4/MGMULAN	22.57	152337

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