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

Panle Jia Barwick Jack Collison Pinelopi Koujianou Goldberg Shanjun Li Yucheng Wang

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Abstract

We study the optimal design of trade and industrial policy when governments pursue environmental objectives alongside traditional welfare goals. Motivated by the global transition to electric vehicles (EVs) and growing concerns about competitiveness, energy security, and climate change, we develop a framework in which policymakers choose tariffs and domestic production subsidies to maximize welfare, defined as the sum of consumer surplus, domestic profits, environmental benefits, and tariff revenue. We combine a theoretical model of differentiated-product oligopoly with a structural demand model estimated using vehicle-level data from 13 countries that together account for the vast majority of global EV sales. Our central finding is that the optimal policy combines a moderate tariff on imported EVs with a subsidy to domestic EV production financed through tariff revenue. This policy substantially outperforms both outright protectionism and laissez-faire. Relative to current policies, it preserves consumer access to affordable EVs, accelerates fleet electrification, supports domestic producers, and remains budget-neutral. For the United States, the optimal policy more than doubles EV market share, generates over $45 billion in annual welfare gains, and avoids approximately 95 million tons of lifetime CO_2 emissions. A key mechanism underlying these results is the pass-through of tariffs and subsidies to prices, which depends critically on demand curvature, product substitution, and market structure. More broadly, our results suggest that effective industrial policy requires careful attention to market structure and country-specific conditions, balancing consumer, producer, fiscal, and environmental objectives rather than adhering to ideological prescriptions.

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[*] Barwick: UW-Madison, CEPR, and NBER, pbarwick@wisc.edu; Collison: UW-Madison, jcollison@wisc.edu; Goldberg: Yale, BREAD, CESifo, CEPR, and NBER, penny.goldberg@yale.edu; Li: Doerr School of Sustainability, FSI and SIEPR, Stanford, and NBER, Shanli@stanford.edu; Wang: University of Sydney, yucheng.wang@sydney.edu.au. We thank Larry Goulder, Bård Harstad, Keith Head, and several seminar participants for helpful comments.

1 Introduction

Recent years have witnessed a resurgence of subsidies and other forms of industrial policy in countries that had largely refrained from their use in the past three decades, most notably the US (Juhász, Lane, and Rodrik, 2024; Juhász et al., 2025; Evenett et al., 2024). Although economists have traditionally been skeptical of industrial policy, several features distinguish the current wave. First, many interventions target genuine market failures and externalities, particularly in the context of energy transition and green growth, with a focus on sectors such as electric vehicles (EVs) and solar panels. Second, national security and resilience to geopolitical risk have become central policy objectives. Third, industrial policy has increasingly relied on (or been implemented in conjunction with) traditional trade policy instruments, such as tariffs and export restrictions, as illustrated by policies targeting the EV, semiconductor, and solar panel sectors. Fourth, the use of industrial policies and trade protectionism by the world's two largest economies, the US and China, has placed other countries in a difficult position, forcing them to balance competing objectives in their responses. In many cases, this has led to recommendations that depart sharply from past practice.[1]

A central dilemma for policymakers is whether to prioritize consumers or domestic producers and workers. A consumer-oriented approach implies abstaining from tariffs and a passive, if not welcoming, stance toward most foreign subsidies, as these reduce prices for domestic consumers. As international economists have often noted, "if a country subsidizes its production and/or exports, we should write a thank-you note." This argument is even stronger in the presence of externalities – for example, when subsidized imports of green technologies help reduce emissions. However, such imports may undermine domestic industries and adversely affect workers. The recent backlash against free trade and multilateralism underscores the importance of taking political economy, and in particular producer and worker responses, into account when setting policy.

These tradeoffs are particularly salient in the EV sector. The global shift from internal combustion engine (ICE) vehicles to EVs represents the most significant transformation in passenger transportation in over a century. Since their mass-market introduction in 2011, EV sales have reached 20.7 million units, accounting for nearly one-quarter of global new vehicle sales by 2025.[2] Adoption, however, varies widely across countries: EVs account for 97% of new vehicle sales in Norway, 69% in Denmark, 54% in China, 29% in Germany, and only 9% in the US (Figure 1).

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[1] For example, the Draghi report on European competitiveness (Draghi, 2024) explicitly advocates policies long resisted in Europe, including subsidies and tariffs. Similarly, a recent World Bank report on industrial policy (Fernandes and Reed, 2026) adopts a more nuanced stance relative to the past, acknowledging that sectoral targeting may at times be warranted.

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

Countries seeking to reduce emissions have a strong interest in promoting EV adoption, including through imports from China. While U.S. producers have largely focused on the high-end segment, Chinese firms have become highly competitive across the full market spectrum, from dominating the low- and mid-range segments to increasingly challenging the premium end. Although the rising global sales of Chinese EVs may be beneficial to consumers seeking affordable EVs, and desirable from an environmental perspective, they pose a significant challenge to domestic EV industries in the US and parts of Europe. Policy responses have included trade protection – prohibitive tariffs in the US, more moderate tariffs elsewhere – domestic subsidies, and growing calls for stronger intervention.

Motivated by these developments, we develop a framework to jointly analyze trade and industrial policy when governments pursue environmental objectives along with traditional welfare, as is the case in the EV sector. Policymakers maximize welfare, defined as the sum of consumer surplus, domestic firm profits, environmental externalities, and tariff revenue, using two instruments: tariffs and subsidies. This framework captures the key tradeoffs in current policy debates between protecting consumers from higher prices, supporting domestic firms through profit shifting under imperfect competition, advancing environmental goals, and managing fiscal balances.

Our analysis proceeds in two steps. We first develop a simple theoretical model in which domestic automakers compete with imported EVs in a differentiated-product oligopoly, yielding analytical insights on how optimal tariffs and subsidies depend on demand curvature, market structure, and the substitutability between domestic and imported products. We then estimate a flexible random-coefficients demand model of the vehicle market (Berry, Levinsohn, and Pakes, 1995) using 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. The richness of our data allows us to estimate a highly flexible empirical specification. Consistent with prior work on cost pass-through, this flexible demand specification is crucial for understanding tariff and subsidy pass-through and therefore for optimal policy design.

Our central result is that the optimal policy package combines a modest tariff with a subsidy to domestic EV production, financed through tariff revenue (i.e., tariff revenue recycling). This policy balances the relevant tradeoffs: it preserves consumer access to affordable imported EVs, supports the domestic industry through protection and subsidization, remains budget-neutral, and promotes EV adoption, thereby reducing emissions and generating environmental benefits. More broadly, our analysis suggests that effective policy requires embracing nuance rather than ideology: moderate tariffs combined with revenue-funded subsidies dominate both extreme protectionism and pure laissez-faire.

We begin by examining the effects of the trade and industrial policies currently in place in the United States and the European Union, namely the US de facto ban on Chinese EVs and the EU's countervailing-duty regime. Two findings emerge. First, outright bans on Chinese EVs impose substantial welfare losses, largely by foreclosing consumer access to affordable EVs and slowing fleet electrification. Second, allowing Chinese EV entry under a combination of moderate tariffs and domestic EV subsidies markedly improves welfare relative to banning: the policy package generates sizable consumer surplus gains and substantial environmental benefits through accelerated EV adoption, while restraining the decline in domestic firm profits and manufacturing employment to moderate levels. Across both the US and the EU, policies that permit entry under moderate tariffs, especially when revenue is recycled into domestic EV subsidies, dominate outright bans.

This finding raises a natural question: among policies that permit entry, what is the welfare-maximizing combination of tariffs and subsidies? We compare four policy regimes: tariff-only, subsidy-only, unconstrained joint use of tariffs and subsidies, and revenue-recycled joint use, in which tariff revenue funds domestic EV subsidies under a balanced budget. The recycling policy shifts the welfare frontier upward, outperforming trade-only or subsidy-only approaches, and closely approximates the unconstrained optimum while remaining budget-neutral. For the US, the welfare-maximizing package combines an approximately 25% tariff with a recycling subsidy of nearly \$7,500 per domestically produced vehicle. Relative to the status quo, this policy more than doubles the EV market share, generates over \$45 billion in annual social welfare gains, avoids approximately 95 million tons of lifetime CO_2 emissions, and limits the implied decline in US auto manufacturing employment to roughly 52,000 jobs, the most favorable combination of outcomes among the alternative scenarios we consider.

The advantage of the tariff-recycling design rests on a pass-through asymmetry that we do not impose a-priori, but recover empirically, directly from the data. On the one hand, the pass-through of the ad valorem tariff is less than one: each additional dollar of tariff revenue raises the US consumer price of Chinese EVs by less than one dollar, as Chinese exporters absorb part of the burden by compressing markups. On the other hand, the pass-through of the domestic subsidy is greater than one: a one-dollar per-vehicle subsidy to US producers lowers domestic EV prices by more than one dollar, because the subsidy not only lowers marginal cost but also induces domestic firms to compress their own pre-existing markups, partially correcting market-power distortions in the domestic EV segment. Together, these two channels generate a "double dividend" that no single instrument can replicate: rents transferred from foreign exporters finance consumer-facing relief on domestic EVs.

Our cross-country comparison highlights that the optimal combination of policy tools depends on the underlying market structure and market power. The optimal tariff is positive in every market we study, reflecting the fact that Chinese exporters absorb part of the burden - a mechanism that operates even when no domestic EV producer exists. The level of the optimal subsidy, by contrast, depends heavily on the presence and size of domestic EV makers and the competitiveness of their products on price and attributes. However, a robust finding across contexts is that in each of these markets, the welfare-maximizing tariff-recycling subsidy policy closely approximates the unconstrained joint optimum.

Our study is related to several literature strands. First, we contribute to the literature on the role of industrial policies, particularly in the context of the green transition and EV adoption (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. A striking feature of recent industrial policies, not only in EVs but also in other sectors, (e.g., solar panels, semiconductors) is that they frequently employ tools of trade policy, such as tariffs and export restrictions (Gerarden et al., 2025; Goldberg et al., 2024). Our paper connects trade policy, industrial policy, and environmental objectives within a unified quantitative framework that allows these interactions to be evaluated jointly and advances the literature by characterizing the optimal policy mix in a specific, highly policy-relevant context.

Second, our paper contributes to the analysis of trade policies under imperfect competition. While the foundational strategic trade policy literature established that governments could shift rents and 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). Rather than examining the robustness of the results to alternative assumptions, we exploit knowledge of the institutional setup to inform relevant assumptions and estimate model parameters based on rich micro data. Specifically, we empirically estimate a flexible differentiated-product equilibrium model of the global automobile market, in which demand curvature, substitution patterns, and passthrough are disciplined by comprehensive data.

Third, 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, passthrough, and market power mediate the effects of tariffs and domestic EV subsidies on market outcomes and welfare.

Our paper is perhaps most similar in spirit to Berry, Levinsohn, and Pakes (1999) and Goldberg (1995), which used differentiated-product oligopoly frameworks to analyze the impacts of an early strategic trade policy, namely voluntary export restraints (VER) on Japanese vehicle exports to the US in the 1980s as well as exchange rate passthrough.[3] While these papers focused on quantity-based trade restrictions and exchange rates, we examine a modern policy package of ad valorem tariffs coupled with revenue-funded subsidies in a setting where trade policy, industrial policy, and environmental objectives interact. We demonstrate that this integrated approach can generate significant welfare gains for the US while simultaneously accelerating the domestic energy transition.

The remainder of the paper is organized as follows. Section 2 presents the theoretical model to build intuition. Sections 3 and 4 describe the data and estimation. Section 5 introduces the counterfactual framework and specific welfare metric used in the empirical analysis. Section 6 evaluates recent trade and industrial policies on Chinese EVs in the US and the EU, motivating our optimal policy analysis. Section 7 characterizes the optimal policy design, demonstrates the welfare dominance of tariff-recycling subsidies, and explores the underlying mechanisms, distributional consequences, and cross-country comparisons. Section 8 concludes.

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[3] There are striking historical parallels between the 1980s VERs on Japanese cars and today's prohibitive tariffs on Chinese EVs; in both cases, the US government leveraged trade barriers to protect the same domestic incumbents from a foreign challenger. Similarly, there are many parallels between exchange rate and tariff passthrough as they both depend on market structure, the nature of competition and demand curvature.

2 Theoretical Model

Consider $j = 1,...,J$ heterogeneous products with marginal cost C_j and demand $Q_j(\tilde{\mathbf{P}},\mathbf{X})$, where $\mathbf{X}$ are non-price characteristics that enter utility. Prices $\tilde{P}_j$ adjust for tariffs on imports with $\tilde{P}_j = (1+\tau)P_j$ for $j \in J_f$ and unit subsidies on domestic goods with $\tilde{P}_j = P_j - b_j$ for $j \in J_d$. Given the policies (τ,b), firms solve the following profit maximization problem:

$$\max_{P_j}(P_j - C_j)Q_j(\tilde{\mathbf{P}},\mathbf{X})$$

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

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 $\gamma = [\tau,b]$. 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.

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

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

where ϕ_j measure externalities induced by good j. The social planner chooses policies $\gamma = (\tau,b)$ 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 obtain:

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

The first-order conditions have four pieces:

1. *Changes in consumer surplus*: Consumer surplus loss (gain) 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 as determined in Equation (2). 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 unit subsidies on domestic goods. 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 with corresponding Monte Carlo simulations, 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). Relative to that paper, 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 (1995), 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.

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.[4] 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.

Policy stances on Chinese EVs vary widely across major developed markets. The US is the most restrictive: Section 301 tariffs were raised to a total of 102.5% in 2024, and the Commerce Department's Connected Vehicle Rule effectively bans most Chinese EV imports. Canada has been similarly restrictive, with a 100% surtax through 2025, although a late-2025 quota arrangement points toward partial reopening. The EU has been substantially more moderate, applying brand-specific countervailing duties ranging from 17.8% to 45.3% on top of its standard 10% MFN tariff. Australia is the most open of the four, with no special tariffs on Chinese EVs and a zero standard tariff on passenger motor vehicles. The resulting penetration of Chinese EVs across these markets tracks the policy gradient closely (Figure 1): the share is essentially zero in the US throughout the sample, rises steadily in the EU after 2020, and exceeds 30% in Australia by 2024. Appendix C.1 provides detailed policy descriptions for each market.

These barriers also raise EV prices in the US. Appendix Table F.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 EU, EV prices remained approximately 27 percent higher than comparable ICE models even after subsidies.

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[4] 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.

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.[5] Among these, nine are European: six European Union (EU) member states (Austria, France, Germany, the Netherlands, Spain, and Sweden) and three non-EU European countries (Norway, Switzerland, and the United Kingdom). Throughout the paper, "EU" refers to the six member states in our sample and "Europe" (or "European countries") to all nine European countries. 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.[6]

Our vehicle attributes data comes mainly from the Teoalida Car Database, supplemented by IHS Markit, Ward's Automotive for the US, and EV Volumes; we manually collect attributes for fringe Chinese models from 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 battery products.

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 incentives (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).

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[5] The 13 countries are Austria, Canada, China, France, Germany, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

[6] 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).

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).[7] 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. Heterogeneous consumers demand vehicles, and firms set prices for their existing vehicle models.

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 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 $\alpha_{im} = \bar{\alpha} + \alpha_m / y_{im} + \sigma^p v^p_{im}$, 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: $\{\alpha_1, \alpha_2, \alpha_3,$ and $\alpha_4\}$.[8] This specification guarantees

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

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

that the (dis)utility of price is homothetic in income. [9] 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. This random coefficient is important for capturing within-brand versus cross-brand substitution patterns.[10] 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 distributed Type I Extreme Value, quantities sold for the product j in the 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 the country m at time t, and market shares are computed by integrating individual choice probabilities.

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[9] Making utility homothetic in price and income is crucial for cross-country estimation: nominal exchange-rate movements (e.g., the 2014 USD appreciation) would otherwise contaminate demand estimates through the units of $\tilde{P}_{jmt}$ and y_{im}. Our specification absorbs these movements through the real ratio $(\tilde{P}_{jmt} - b_{jmt})/y_{im}$.

[10] 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.

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.[11] 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:

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

Stacking the first-order conditions and inverting Δ yields the equilibrium price vector $\mathbf{p}^*$ as a function of marginal costs and the equilibrium markup:

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

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[11] As standard in studies of the automobile market, we assume automakers engage in Bertrand competition rather than Cournot because automakers primarily compete through price adjustments and incentives in a market characterized by highly differentiated products. Unlike Cournot models, this framework more accurately reflects the short-run flexibility of pricing relative to rigid production capacities. From an empirical standpoint, the Bertrand framework facilitates the structural estimation of markups and marginal costs by leveraging observed price data and estimated demand elasticities.

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 B.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.[12] 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:

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

Micro-Moments We also include two sets of micro-moments to identify preference parameters. The first set 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

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[12] 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.

(2015), and the Netherlands (2019) and match the observed share of EV buyers within specific income brackets to the corresponding model-predicted share.[13] 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 to capture heterogeneous preferences across consumers. The signs of the coefficients match those in Column (2). 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 CHN, with UK/NL/AT/SE and CA/NO/US/CH much smaller. All of the income coefficients are positive, meaning that high-income households are less price-sensitive than their lower-income counterparts. Brand-preference random coefficients govern within-brand substitution patterns. The coefficient for US+CA is the largest, followed by smaller European countries. 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 European countries are much smaller, consistent with more market fragmentation and less strong brand preferences.

The estimated average own-price elasticity is -2.62, in line with the existing literature on combined EV and ICE demand (Grieco, Murry, and Yurukoglu, 2024) and with previous estimates of global EV demand elasticity in the range -2 to -4 (Barwick et al., 2025; Li et al., 2017), since EV buyers tend to have higher incomes and are less price-sensitive. Price semi-elasticities (the percentage change in sales for a \$1,000 decrease in a vehicle model's consumer-facing price) are

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[13] 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.

larger in magnitude for less expensive vehicles, consistent with the estimated income coefficients: consumers who buy cheaper vehicles typically have lower incomes. Panel (a) of Appendix Figure E.4 reports the histogram of own-price elasticities; Panel (b) reports the price semi-elasticities by country group.

We also validate the estimated demand system out of sample: the model, estimated using data through 2023, simulates the effects of the EU countervailing duties and closely matches the post-policy market shifts identified empirically using actual data from 2024 and 2025.[14]

5 Counterfactual Framework

5.1 Welfare Objective

The empirical welfare measure we adopt is the direct analog to the social planner's objective in our theoretical framework (Equation 3). We evaluate each policy regime relative to the 2023 status quo using the welfare change:

$$\Delta\text{Welfare} = \Delta CS + \Delta\Pi^{\text{dom}} + \Delta\text{GovRevenue} + \Delta\text{EnvBenefits}, \tag{8}$$

where ΔCS is the change in consumer surplus, $\Delta\Pi^{\text{dom}}$ is the change in domestic firm profits, ΔGovRevenue is the net change in government revenue from tariff collections minus subsidy expenditures, and ΔEnvBenefits is the change in environmental benefits. We also consider a marginal cost of public funds (MCPF) adjustment that penalizes net fiscal deficits, as well as an alternative welfare measure that explicitly accounts for the value of domestic jobs and which is described at the end of this subsection.

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

$$CS = \int \frac{1}{\alpha_i} \log\Big(1 + \sum_{j\in\mathscr{J}} \exp(\delta_j + \mu_{ij})\Big)\, dF(\mu_{ij}) \;+\; \text{constant}, \tag{9}$$

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 cancels in differences, so it plays no role in ΔCS.

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[14] Section 6.2 reports the model-simulated effects of the EU CVD (Table 3); Appendix D confronts these simulated predictions with the realized 2024–2025 registration data using a synthetic-control event study, and recovers a closely matching contraction in incumbent Chinese-brand EU sales.

Environmental benefits. We measure environmental benefits from policy-induced reductions in ICE sales, converting the change in equilibrium ICE sales ΔQ^{ICE} into avoided lifetime external damages from (i) CO_2 emissions and (ii) local air pollution:

$$\Delta \mathrm{EnvBenefits} = -\Delta Q^{\mathrm{ICE}} \cdot \big(\mathrm{UnitCarbCost} + \mathrm{UnitHealthCost}\big), \tag{10}$$

where UnitCarbCost and UnitHealthCost are per-vehicle lifetime external costs calibrated from Funke et al. (2023); details and the physical-unit CO_2 conversion are in Appendix C.3.

Value of jobs. We also augment the welfare measure with a monetized job-value term, $\Delta \mathrm{Welfare}^{\mathrm{Job}}(w) = \Delta \mathrm{Welfare} + w \cdot \Delta \mathrm{Jobs}$, where ΔJobs maps equilibrium domestic sales into US manufacturing jobs and w is the annualized social value per job. Construction details, jobs-per-vehicle calibrations, and per-job-year benchmarks (with bounds from Slattery, 2025 and BLS NAICS 336) are in Appendix C.4.

5.2 Counterfactual Implementation

For each policy regime, we re-solve the Nash-Bertrand pricing equilibrium under the specified policy parameters and compute the welfare change defined above.[15] The policy instruments we consider are ad valorem tariffs on Chinese EVs and per-unit subsidies on domestically produced EVs, in isolation or in combination, with or without a balanced-budget revenue-recycling constraint.

How we treat Chinese EVs differs across exercises. In our evaluation of recent EU trade remedies (Section 6), Chinese EVs are already present in the EU market, so we apply the procedure directly using the estimated mean utilities and marginal costs of the observed Chinese EV models. For the counterfactual Chinese EV entry into the US (Section 6) and the optimal-policy analysis across the US, Germany, the UK, and Spain (Section 7), we instead exogenously introduce a fixed set of entrants into the focal market: the top 10 China-manufactured EV models ranked by their 2023 Chinese market shares.[16] These are mainstream, high-volume models produced by major incumbent automakers (e.g., BYD, SAIC, GAC), rather than niche models from smaller EV startups.[17] These "off-the-shelf" models would be among the most likely candidates to enter if domestic restrictions were lifted. As a robustness check, we repeat the analysis using the top 10 China-manufactured EV models currently sold in Europe.

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

[16] Appendix Table F.2 lists the top 10 Chinese EV models, which together account for 34.3% of the Chinese EV market in 2023; Appendix Figure E.5 shows the full market-share distribution of the top 50 models for context.

[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.

To bring the introduced models into the focal market for the counterfactual, we construct their mean utility and marginal cost from cross-market information for comparable products; details are provided in Appendix C.2. For the US, "bringing Chinese EVs into the market" presumes the Commerce Department's Connected Vehicle restriction is also lifted, since the current de facto ban reflects both prohibitive tariffs and this non-tariff barrier (Section 3). We also abstract from two margins of endogenous response: Chinese EV makers' model choice, and domestic automakers' product repositioning.[18]

6 Welfare Effects of Recent Policies on Chinese EVs

This section applies the counterfactual framework of Section 5 to evaluate recent and ongoing trade and industrial policies targeting Chinese EVs. We focus on two policy environments: the US, where the current regime amounts to a de facto ban, and the EU, where countervailing duties were introduced in late 2024 alongside negotiations over minimum price commitments.

6.1 Recent US Tariff and Subsidy Scenarios

Policy Scenarios. We examine a range of scenarios under alternative US–China tariff rates and US domestic subsidy schemes. Column (1) in Table 2 reports the 2023 status quo (no Chinese EV entry, no domestic EV policy) as a reference baseline. Column (2) maintains the Chinese EV ban while providing a $7,500 EV incentive to US-domestically manufactured EVs, mimicking the domestic-content requirement 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 under different combinations of trade and subsidy policies.

Columns (3) to (6) consider alternative tariff policies. Column (3) imposes no additional tariffs beyond the standard 2.5% tariff. Column (4) adds a 25% tariff, and Column (5) a 100% tariff.[19] 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.[20] Finally, Column (7) introduces Chinese EVs while US-domestically manufactured EVs continue to receive the $7,500 subsidy, aligning with an industrial policy aimed at fostering the domestic EV industry under free trade.

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[18] As a holistic analysis, we complement this static baseline with a perturbation exercise in which we exogenously add EV models to the domestic automaker portfolio, simulating the latter response as a robustness check; see Section 7.

[19] These rates correspond to the Section 301 tariff levels imposed under the first Trump administration (25%) and the early Biden administration (100%).

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

Results. Table 2 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. 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 18.92% under the minimum-tariff scenario (Column 3), and then gradually declines to 11.6% as tariffs increase; the tariff-recycling subsidy falls in the middle of this range, while the free-trade scenario with a domestic industrial policy in Column (7) delivers the highest EV share. The price drop is driven by product composition: incumbent non-Chinese EVs are priced about $9,500 higher than comparable ICE vehicles in the status quo (helping explain the low US EV adoption rate), while the introduced Chinese models are priced well below both incumbent US EVs and ICE vehicles owing to substantially lower estimated marginal costs.

Second, the effects on domestic production and employment provide 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, with the model implying roughly 87 thousand fewer US manufacturing jobs relative to the status quo.[21] As tariffs increase, Chinese EVs lose market share but remain competitive: even under the most aggressive tariff (102.5%), they still account for about 30.6% of the US EV market. This 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. When tariff revenues are recycled as subsidies to US domestic EV manufacturers, the Chinese EV market share falls further to below 20%, highlighting that targeted industrial policy can more effectively limit foreign penetration than tariffs alone.

Third, introducing the top 10 Chinese EV models increases social welfare by more than $30 billion across all policy scenarios, driven primarily by higher consumer surplus. 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 (Column 7), but at the cost of substantial ICE-segment declines, since domestic ICE models face intensive competition from both Chinese and subsidized domestic EVs without offsetting innovation or product repositioning.

Conditional on trade policy alone, the highest welfare is achieved under the mild tariff (Column 3); the aggressive tariff regime delivers the lowest welfare gain, while recycling tariff revenues (Column 6) increases welfare by about 13%. Under tariffs alone (Columns 3–5), US domestic

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[21] The resulting job measure is the sum of jobs attributed to domestic production by US firms and incumbent transplants. Job changes are reported relative to the 2023 status quo.

automakers lose profits in both segments. Under the tariff-recycling subsidy policy (Column 6), in contrast, they gain \$7.3 billion in EV profits while losing \$4.2 billion in ICE profits, implying a positive net change in domestic profits and narrowing the implied manufacturing employment loss to about 11,000 jobs. Under recycling, the primary losers shift to non-US incumbent automakers (European, Korean, Japanese firms).

The qualitative findings are robust along three dimensions. Replacing the entrant set with the top ten China-manufactured EVs currently sold in Europe preserves all patterns, with magnitudes roughly half as large (Appendix Table F.3). Varying the construction of fixed effects and ξ components leaves the simulated US EV market share under each policy scenario stable (Appendix Figure E.6). Extending the analysis backward to 2014–2023 shows how Chinese EV entry would have shifted the historical EV adoption trajectory (Appendix Figure E.7).

6.2 European Union Trade Remedy Scenarios

Policy Scenarios. In 2023, Chinese EVs are already present in the EU market under the existing 10% MFN tariff, embedded in the 2023 observed prices. All counterfactuals operate on the existing Chinese EV models in the 2023 sample; no additional entrants are introduced. Column (1) in Table 3 captures the status quo. Column (2) applies the EU's October 2024 brand-specific countervailing duties (CVD) on top of the existing 10% MFN.[22] Column (3) retains the same CVD tariff structure but recycles the resulting revenue as a uniform per-vehicle subsidy to EU-member-manufactured EVs, with the subsidy rate determined jointly across all six member states to satisfy budget balance. Column (4) models a Minimum Price Commitment (MPC), the price-side analog of a voluntary export restraint (VER), in which Chinese exporters voluntarily commit to a minimum export price.[23] If set at the CVD-inclusive equilibrium level, the MPC and CVD are isomorphic, producing identical consumer prices, quantities, and EV adoption rates; they differ only in the disposition of the tariff wedge, which flows to the EU government as revenue under CVD and is retained by Chinese firms as export rents under MPC. Column (5) is a counterfactual ban that removes all existing Chinese EV models from the EU market.

Results. Table 3 reports the results. Four takeaways stand out. First, the EU's October 2024 CVD (Column 2) reduces Chinese EV competition substantially: the Chinese share of EV sales falls from 9.89% in the benchmark to 4.50%, and the sales-weighted Chinese EV price rises from \$54,720 to \$71,550. Total EU welfare falls modestly by \$0.11 billion, as the tariff revenue gain of

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[22] +17% for BYD, +18.8% for Geely-group brands, and +35.3% for all other Chinese brands.

[23] In early 2026, the EU and China reached a bilateral framework under which several major Chinese automakers, including BYD and SAIC, agreed to minimum export price commitments as an alternative to the October 2024 countervailing duties; Column (4) operationalizes this type of arrangement.

\$1.41 billion only partially offsets the consumer surplus loss of \$2.22 billion; EU domestic firm profits rise by \$1.15 billion as reduced Chinese competition benefits both the EV and ICE segments. Second, recycling the CVD revenue as a per-vehicle subsidy to EU-member EVs (Column 3) reverses the welfare loss, yielding a gain of \$1.23 billion, the highest across all four policy columns. By converting tariff revenue into demand-stimulating subsidies, the recycling policy raises EU domestic EV firm profits by \$1.87 billion and lifts the EU-wide EV share to 23.74%, partially offsetting the consumer surplus loss from higher Chinese EV prices. This mirrors the central result from the US analysis: recycling tariff revenue raises total welfare. Third, the MPC (Column 4) generates identical equilibrium prices, quantities, and EV adoption as the CVD, so consumer surplus and domestic firm profits are unchanged. The welfare gap ($-$\$0.11 billion under CVD versus $-$\$1.52 billion under MPC) reflects entirely the redistribution of the \$1.41 billion tariff wedge, which under MPC flows to Chinese exporters as export rents rather than to the EU Treasury, mirroring the classic finding of Berry, Levinsohn, and Pakes (1999) on voluntary export restraints. Fourth, removing all Chinese EVs from the EU market (Column 5) generates the largest welfare loss of $-$\$5.00 billion: the consumer surplus loss of \$5.64 billion, substantially larger than under any tariff scenario, reflects the elimination of competitively-priced Chinese EVs and the pass-through of reduced competition to non-Chinese EV makers, whose sales-weighted average price rises from \$62,300 to \$62,580. The EU-wide EV share falls from 23.81% to 22.54%, generating an environmental cost of \$0.79 billion; EU domestic firm profits rise by \$2.57 billion (\$1.56 billion EV, \$1.01 billion ICE), and the EU forfeits \$1.15 billion in baseline MFN tariff revenue. Together, these effects make an outright ban the most costly policy among those considered.

We test the Column 2 predictions empirically and out of sample: a synthetic-control event study (Appendix Figure E.8) on post-policy EU registration data (2024–2025) recovers a 57.4% post-CVD contraction in incumbent Chinese-brand EV sales, closely matching the model-implied 56.0% decline. The data and design are detailed in Appendix D.

7 Optimal Policy Design

The US and EU exercises together highlight two robust welfare patterns. First, prohibitive tariffs impose substantial welfare losses, as the consumer surplus forgone from restricting competitively priced imports dominates the producer-surplus gains from protection. Second, in both markets, policies that recycle tariff revenue into subsidies for domestically produced EVs deliver higher welfare than tariffs or subsidies in isolation. These results raise a natural question: what combination of tariffs and subsidies is welfare-maximizing, and how closely can a budget-balanced tariff-recycling subsidy approximate that optimum?

7.1 Comparing Optimal Policies Across Regimes

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. Panel (a) of Figure 2 plots the welfare contour for the U.S. market over the tariff-subsidy policy space.

Relationship Between Tariffs and Subsidies as Policy Tools. Tariffs and domestic subsidies act as substitutes in the optimal policy mix: as the tariff rate increases, the welfare-maximizing subsidy declines, and vice versa (red dashed and dotted lines). Both instruments improve the competitive position of domestic EVs relative to Chinese entrants, so the marginal value of one falls as more of the other is used. 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. The magnitude of this substitution depends on the breadth of Chinese entry (Appendix Figure E.9): when Chinese entry is limited, the optimal subsidy changes little across tariff regimes; with broader entry, the reduction in the optimal subsidy is more pronounced, because the tariff already provides a greater degree of protection.

Comparing Across Optimal Policy Scenarios. Tariff recycling closely approximates the unconstrained optimum 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, delivering nearly identical welfare to the unconstrained optimum. The unconstrained optimum lies above the recycling line, so it implies a fiscal deficit relative to the balanced-budget allocation. The two policies converge as the government places greater weight on budget balance, or, equivalently, as the marginal cost of raising public funds rises.

Appendix Figure E.10 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 unconstrained optimum and generally dominates the single-instrument alternatives.[24]

Table 4 provides a richer comparison across optimal policy regimes for the benchmark $N = 10$ case. The unconstrained joint policy delivers a welfare gain of $45.45 billion, while the optimal recycling policy delivers $45.33 billion. Relative to the tariff-only regime, recycling raises EV adoption from 16.06% to 19.60%, increases environmental benefits from $3.66 billion to $5.47 billion, and reduces the decline in US firm profits from $-8.70 billion to $-3.24 billion. Recycling is also more politically feasible than either the subsidy-only regime or the unconstrained optimum, since it avoids the large government outlays they require ($14.77 billion and $3.01 billion, respectively).

The bottom two rows of Table 4 report the corresponding employment and emission impacts. Tariff recycling delivers nearly the largest environmental gain among the four entry-permitting regimes, avoiding 95.44 million tons of lifetime CO_2 emissions. Recycling also yields the smallest employment loss, at about 52,000 manufacturing jobs. At the same time, Chinese EV entry creates downstream service jobs through market expansion: under recycling, total new-vehicle sales rise by approximately 508,000 units, supporting roughly 20,300 net new service jobs and offsetting about 39% of the manufacturing loss.

Domestic Automaker Product Entry. The baseline analysis holds domestic automakers' product portfolios fixed, so firms respond to Chinese EV entry only through prices. In practice, they may also expand their EV lineups. We conduct a perturbation exercise in which we exogenously add one or three EV models to the domestic portfolio by reassigning major third-country EVs to Tesla and Volkswagen, holding product characteristics fixed. Table F.4 reports the results for the US (first three columns) and Germany (last three columns). Three findings stand out.

First, expanding the domestic product line shifts both optimal instruments, though directions vary across regimes. The per-unit subsidy rises in Subsidy Only and Unconstrained Optimum regimes (stronger infant-industry motive with more domestic models), but falls in Tariff-funded Subsidy because a roughly fixed revenue pool must cover a larger eligible base. The optimal tariff rises in Tariff Only and Tariff-funded Subsidy (more domestic models strengthen protection / require more revenue), while staying essentially flat at 21.5% in the Unconstrained Optimum, where the planner accommodates the broader portfolio through subsidies rather than additional tariffs (the optimal subsidy rises from $8.50k to $9.00k per vehicle), exploiting tariff-subsidy substitutability.

Second, the main policy conclusions are robust: optimal tariff and subsidy choices remain relatively stable, and the tariff-funded subsidy regime remains close to the unconstrained optimum

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[24] Appendix Figures E.11 shows that the same pattern holds for $N = 5$ and $N = 20$, with the exact recycling tariff slightly above or below the unconstrained optimum but the welfare distance remaining small.

regardless of whether domestic product entry is allowed.

Third, social welfare increases substantially with domestic product expansion. Under the tariff-funded subsidy regime, adding one domestic EV model raises welfare from \$45.60 billion to \$48.65 billion, and adding three models raises it further to \$51.78 billion. This result suggests that if domestic automakers can endogenously adjust their product portfolios in response to Chinese competition, the gains from combining domestic product expansion with the optimal tariff policy could be even larger than in our baseline static setting.

7.2 The Effects of Optimal Tariff-Recycling Subsidy

Figure 3 decomposes welfare against the tariff rate under the top-10 Chinese EV entry scenario, comparing the no-recycling and revenue-recycling regimes. Under recycling, each candidate tariff is matched to the subsidy implied by the balanced-budget constraint, and we search over a tariff grid for the optimum. Three findings stand out. First, social welfare is hump-shaped in the tariff rate under both regimes, and the welfare-maximizing tariff is lower under recycling (25.0 percent) than under no-recycling (27.5 percent), because less aggressive protection is needed once tariff revenues are returned as domestic EV subsidies. Second, recycling shifts the welfare frontier upward across nearly the entire tariff range and, at any given tariff rate, sustains a markedly higher EV market share, better preserving electrification while still limiting Chinese EV penetration. Third, these gains arise because recycling preserves consumer surplus and EV adoption while also improving US producer profits, relaxing the trade-off facing tariff-only policies: protecting domestic producers otherwise comes at the expense of consumer surplus and environmental benefits.[25]

Figure 4 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 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 117.7 percent and lowers the average EV price by 25.4 percent. The welfare decomposition in Panel (b) shows that these gains are driven primarily by a \$43.10 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. The job value bars further illustrate the employment trade-off: the lower and upper bounds capture the range of social

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[25] Appendix Figure E.13 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%).

costs associated with manufacturing job losses under each entry scenario. Specifically, under the top-10 entry scenario with the optimal tariff-recycling policy, manufacturing employment falls by approximately 52,000 jobs, reflecting the displacement of domestic auto production by Chinese EV imports. The increase in EV adoption avoids roughly 95 million tons of lifetime CO_2 emissions, underscoring the substantial climate co-benefits of allowing lower-cost Chinese EVs into the market.

Welfare with Value of Jobs. A central rationale for trade and industrial protection is the value of preserving domestic manufacturing employment. We augment the baseline aggregator with a monetized job-value term.[26]

Appendix Table F.5 reports the implied optimal welfare under each benchmark. At the lower bound ($10,700/job-year (Slattery, 2025)), the findings are essentially unchanged, with optimal recycling welfare falling modestly to $44.78 billion and the ranking of policy regimes preserved. At the upper bound ($70,000/job-year, the BLS NAICS 336 average wage), recycling welfare drops to $41.70 billion and remains close to the joint unconstrained optimum. For comparison, Allcott et al. (2026) estimate that the IRA delivered each additional US auto-manufacturing job at a fiscal cost of $169,000;[27] plugging this figure into our welfare aggregator, optimal recycling still delivers $36.55 billion in welfare gain.

Appendix Figure E.14 shows how the welfare-maximizing policy itself shifts when the planner internalizes the value of jobs: as the per-job-year valuation w rises, the optimum moves to higher tariff rates and larger recycling subsidies, since broader Chinese EV entry at lower tariffs amplifies domestic job displacement.

Welfare with MCPF. A second extension incorporates the marginal cost of public funds (MCPF): financing subsidies through distortionary taxation imposes a deadweight loss that the baseline aggregator omits (Ballard, Shoven, and Whalley, 1985; Dahlby, 2008; Goulder and Williams, 2003). We penalize net fiscal deficits at multiplier χ.[28]

The lower panel of Appendix Table F.5 reports MCPF-adjusted welfare. The penalty binds only on regimes that run a deficit: Tariff Only generates a surplus and Recycling balances the budget

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[26] The construction proceeds in two steps: we first map equilibrium domestic sales into US auto-manufacturing employment using constant jobs-per-vehicle coefficients differentiated by ICE versus EV, and we then multiply the implied change in employment by a per-job-year social value. Appendix C.4 provides the full formulas and describes the five per-job-year benchmarks we consider.

[27] They take a complementary look at US auto-industry policy by evaluating the welfare consequences of the IRA's EV credits using rich transaction-level data on US new vehicle sales and registrations.

[28] A net fiscal deficit of one dollar carries a social cost of χ dollars: one dollar of direct fiscal outlay plus an additional $(\chi - 1)$ dollars of deadweight loss from raising the revenue through distortionary taxation; a fiscal surplus is returned lump-sum at par. Appendix C.5 describes the construction and motivates the range $\chi \in \{1.1, 1.3, 1.5\}$.

by construction, so both are invariant to χ, while Subsidy Only and the unconstrained Both regime are penalized. By $\chi = 1.3$, Recycling already overtakes Both and Subsidy Only drops below Tariff Only; Recycling dominates across all χ. Once the cost of raising public funds is taken seriously, the case for stand-alone subsidies weakens and the case for tariff-recycling, which is self-financing by construction, strengthens.

7.3 Mechanisms: Pass-through and Markups

Policy Pass-through. We compute pass-through rates for both the tariff and subsidy components, since pass-through is a first-order determinant of aggregate outcomes in counterfactual trade-policy experiments (Head and Mayer, 2026). Because 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.[29] For the recycling subsidy, we analogously define pass-through as the reduction in consumer prices per dollar of per-vehicle subsidy expenditure. Appendix B.2 gives the full formula when the policy applies to multiple products with strategic price responses.

Figure 5 reveals a clear asymmetry. Chinese entrant EVs exhibit incomplete tariff pass-through: firms absorb part of the tariff burden by compressing their tax-exclusive markups rather than passing the full cost to consumers. The ad valorem structure of the tariff is central to this result, since under imperfect competition ad valorem taxes are more likely than specific taxes to generate incomplete pass-through (Delipalla and Keen, 1992; Anderson, De Palma, and Kreider, 2001).[30]

By contrast, US-branded EVs that receive the recycling subsidy display persistent overshifting: domestic EV prices fall by more than the per-vehicle subsidy expenditure. This is consistent with Goldberg (1995), Goldberg and Hellerstein (2013), and Miravete, Seim, and Thurk (2023), who find that pass-through in mixed logit models with rich consumer heterogeneity can exceed one. Together, incomplete tariff pass-through on Chinese entrants and over-complete subsidy pass-through on US incumbents deliver the dual advantage of the tariff-recycling policy.

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[29] In the standard additive-cost case, pass-through is defined as $\Delta\text{price}/\Delta\text{marginal cost}$; see Weyl and Fabinger (2013) and Miravete, Seim, and Thurk (2023).

[30] 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 $T = \tau x$. Hence $dP/dT = 1 + (dx/d\tau)/(x + \tau dx/d\tau)$. If firms optimally reduce x as τ rises ($dx/d\tau < 0$), pass-through with respect to tariff payments falls below one. This incomplete pass-through under variable-markup oligopolistic competition is a well-established result, derived for example in the nested CES with Nash-Bertrand framework of Atkeson and Burstein (2008) and confirmed empirically in Chinese firm-level customs data from the US-China trade war by Fan et al. (2025). Our random-coefficient logit framework retains the share-dependence channel of Atkeson and Burstein (2008) and adds a second channel, heterogeneity in price sensitivity across income groups (Anderson, De Palma, and Kreider, 2001; Miravete, Seim, and Thurk, 2023), which can flip the sign of the firm's ex-tariff price response in some regions of the demand curve, generating over-shifting. Appendix B.2 provides the formal comparison between specific and ad valorem pass-through for a single-product firm.

Market Structure and Markups. These pass-through asymmetries are rooted in systematic differences in pricing, markup, demand curvature, and local market power between Chinese entrant EVs and US incumbent EVs that hold both before and after policy intervention (Appendix Figure E.15). Under the no-policy benchmark, Chinese entrant EVs combine high local market power (high Lerner indices) with relatively flat demand curvature, placing them in the low-price, high-market-share region of the demand curve, just as illustrated in Appendix Figure E.16. Both features push tariff pass-through below one: firms have both the ability (high markups) and the incentive (stable elasticity) to absorb part of the tariff shock through markup compression. US incumbent EVs sit in the opposite region of the demand curve, near the "elbow" where curvature is high. When a subsidy lowers their effective price, additional middle-income consumers are drawn into the market, making demand more elastic and amplifying pass-through above one.

Once the tariff-recycling policy is in place, the two groups move in opposite directions: Chinese entrants shift toward lower markups, lower Lerner indices, and higher curvature, while US incumbents move into a region of even stronger subsidy pass-through. The policy thus reshapes competition by compressing the markups of Chinese EVs while strengthening the pricing position of US EVs, an asymmetry that no single-instrument policy can replicate.

7.4 Winners and Losers

Households by Income Distribution. Table 5 reports EV adoption and consumer surplus changes by income quartile under optimal policy regimes (Q4 = wealthiest). Under the subsidy-based regimes (Columns 3 and 4), welfare gains concentrate among higher-income households, since incumbent EVs sit at the upper end of the price distribution and a uniform subsidy accrues disproportionately to consumers already likely to buy an EV.

In contrast, introducing Chinese EV models (Columns 2–5) generates more equitable gains, concentrated in the middle of the income distribution (especially Q3). The introduced Chinese EV models are priced closer to mainstream ICE vehicles than to incumbent EVs, expanding the EV choice set for middle-income households that are priced out of incumbent EVs in the status quo.

Firms. Figure 6 plots changes in EV profits against changes in ICE profits under four optimal policy scenarios. Under the optimal tariff-only regime (top left), Chinese EV entry harms all incumbent producers across both segments. Tesla is the largest loser owing to its heavy EV exposure, while GM and Ford face moderate losses.

Under the optimal tariff-funded subsidy (top right), Tesla becomes the clear winner with over \$2 billion in EV profits, and GM and Ford shift into positive EV-profit territory, though continued ICE losses partly offset these gains. Several firms (Tesla, GM, Ford) end up above the zero-sum boundary indicated by the grey diagonal, experiencing a net increase in total profits. The unconstrained optimum (bottom right) produces a similar pattern. Under the subsidy-only scenario (bottom left), by contrast, the absence of tariffs allows Chinese EVs to compete more aggressively, generating larger ICE losses that more than offset Tesla and GM's EV-profit gains for most firms.

Overall, subsidy-inclusive scenarios disproportionately benefit firms with a larger EV footprint: Tesla emerges as the largest winner, GM and Ford gain in EVs but lose in ICEs (with EV gains often insufficient to offset), and incumbent non-US automakers (European, Japanese, and Korean firms) experience profit declines across both segments.

7.5 Cross-Country Comparisons

We extend the analysis to three additional countries that, together with the US, span the spectrum of domestic EV industry structure: Germany (broad domestic EV base across multiple price tiers), the United Kingdom (ultra-premium domestic EV production only), and Spain (no domestically headquartered EV producer). Table 6 reports the optimal policy results for all four markets side by side, with the detailed US decomposition also available in Table 4.

Germany versus the United States. Figure 2 compares the welfare contours and optimal policy combinations for the US and Germany. A striking difference emerges in the role of the domestic subsidy: in the unconstrained optimum, the welfare-maximizing subsidy for Germany is \$10.60k per vehicle, higher than the \$8.40k for the US. The intuition lies in the breadth of the domestic EV portfolio. Germany hosts sixty-one domestic EV models (Volkswagen, BMW, Mercedes, Audi, Porsche, and other domestically headquartered brands), compared to sixteen in the US (dominated by Tesla, GM, Ford, Rivian, and Lucid). Because the subsidy is paid per domestic-EV unit, a wider portfolio leverages each dollar of subsidy across a larger and more diversified domestic base, raising both the producer-surplus return and the EV adoption response per dollar. German domestic EVs are also more expensive than their US counterparts (sales-weighted average prices of \$75k vs. \$50k under the status quo), so closing the larger price gap relative to Chinese entrants requires a correspondingly larger subsidy.

The optimal tariff is also higher in Germany than in the US. Two forces underlie this difference. First, pass-through is lower in Germany, implying that foreign exporters absorb a larger share of the tariff burden, and making higher tariffs more attractive. Second, the broader domestic EV portfolio strengthens the profit shifting rationale, since more domestic products are available to absorb demand diverted away from Chinese imports.

While the specific size of tariffs and subsidies is context-specific, a robust feature emerges across the two markets: the tariff-funded subsidy policy is closely aligned with the unconstrained optimum in each. The high tariff revenue generated by the profit-shifting motive roughly covers the high subsidy expenditure called for by the infant-industry motive, so the unconstrained optimum is essentially self-financing. This pattern is also consistent with our EU-wide finding in Section 6, where the CVD-with-recycling scenario yields the highest welfare among the EU policy alternatives we consider.

The United Kingdom and Spain. Table 6 extends the comparison to the United Kingdom and Spain. Spain provides a useful limiting case: with no domestically headquartered EV producer, the optimal subsidy is zero across all policy regimes, and the policy problem reduces to the choice of the optimal tariff. The optimal tariff for Spain is strictly positive (17.5%), reflecting the incomplete pass-through of tariffs to consumer prices.

Comparing the four markets reveals two clean monotone patterns. The optimal tariff rises with the number of domestic EV models (17.5% for Spain with 0 models, 20.0% for the UK with 8, 22.5% for the US with 16, and 37.5% for Germany with 61), because a broader domestic portfolio amplifies the demand-diversion and profit-shifting gains from protection. The optimal subsidy instead rises with the average markup of domestic EVs (zero for Spain, \$8.40k for the US, \$10.60k for Germany, and \$12.80k for the UK), as correcting the market-power distortion created by high domestic markups is among the subsidy's main rationales.

8 Conclusion

The resurgence of industrial policy has reignited a longstanding debate about the appropriate role of government intervention in markets. In the context of the global transition to electric vehicles, policymakers face a particularly challenging set of tradeoffs. On the one hand, access to affordable imported EVs promotes consumer welfare and accelerates decarbonization. On the other hand, concerns about competitiveness, domestic production, employment, and economic resilience have led many governments to adopt tariffs, subsidies, and other forms of intervention. This paper develops a framework for evaluating these tradeoffs jointly and for designing policies that balance environmental, consumer, producer, and fiscal objectives.

Combining a theoretical model of differentiated-product oligopoly with a structural model estimated using data from 13 countries, we characterize the optimal use of tariffs and domestic production subsidies. Our results show that the effects of these policies depend critically on market structure, competitive conditions, demand responses, and the size of the domestic sector. Consequently, the precise welfare-maximizing policy differs across countries. While optimal tariffs are generally positive, reflecting the ability of governments to capture part of foreign producers' rents, the optimal subsidy varies substantially with the strength and competitiveness of the domestic EV sector.

At the same time, our analysis delivers a robust and broader lesson. Across a wide range of market environments, policy packages that combine instruments outperform policies that rely on a single tool. In particular, the joint use of tariffs and domestic EV subsidies, financed through tariff revenues, consistently generates outcomes that are close to the unconstrained optimum while remaining fiscally sustainable. Relative to tariff-only policies, revenue recycling preserves consumer access to affordable EVs and supports faster electrification. Relative to subsidy-only policies, it avoids large fiscal costs while maintaining support for domestic producers.

More broadly, our findings suggest that effective industrial policy requires careful attention to market structure and country-specific conditions rather than adherence to universal prescriptions. Yet recognizing the importance of context does not imply the absence of general lessons. If anything, our results point to a common principle: when governments pursue multiple objectives simultaneously, coordinated policy packages that combine complementary instruments and recycle revenues productively are likely to outperform simpler interventions. As countries increasingly turn to industrial policy to address climate, competitiveness, and security concerns, understanding these interactions will be essential for designing policies that achieve multiple objectives without sacrificing economic welfare.

We conclude with some thoughts for future research. Our analysis takes product portfolios and production locations as given and should therefore be interpreted as capturing the short- to medium-run effects of trade and industrial policy. Understanding the long-run consequences of these policies requires endogenizing firms' product-entry and location decisions, allowing domestic automakers to expand their EV offerings in response to intensified competition. More broadly, trade barriers may reshape the geography of production and global supply chains. Just as the voluntary export restraints of the 1980s contributed to the expansion of Japanese transplant manufacturing in the United States, today's tariffs may encourage Chinese automakers to establish production facilities in North America and other destination markets. How firms adapt their product strategies, production locations, and supply-chain networks in response to trade and industrial policies remains an important question for future research and for understanding the next phase of the global energy transition.

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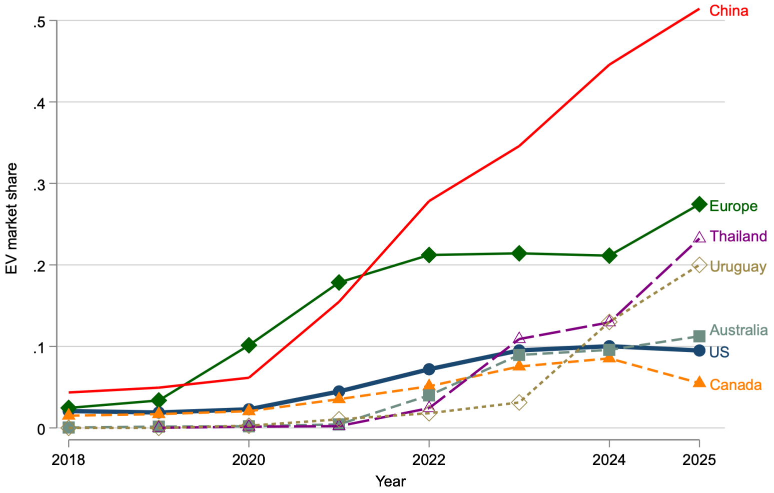
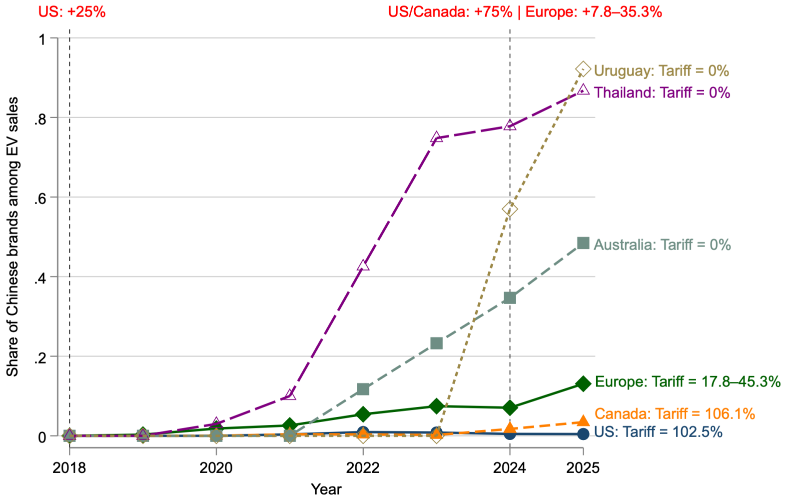
Figures & Tables

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

(a) EV adoption across markets



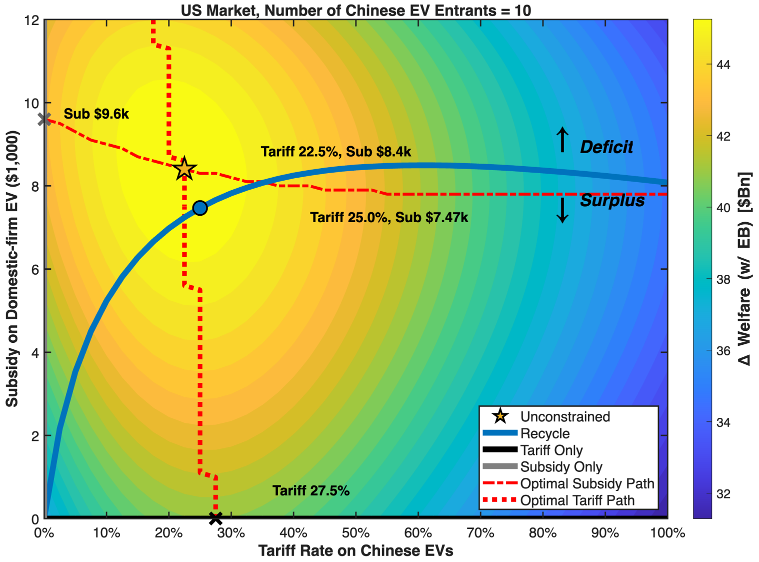
(b) Share of China-manufactured EVs of total EV



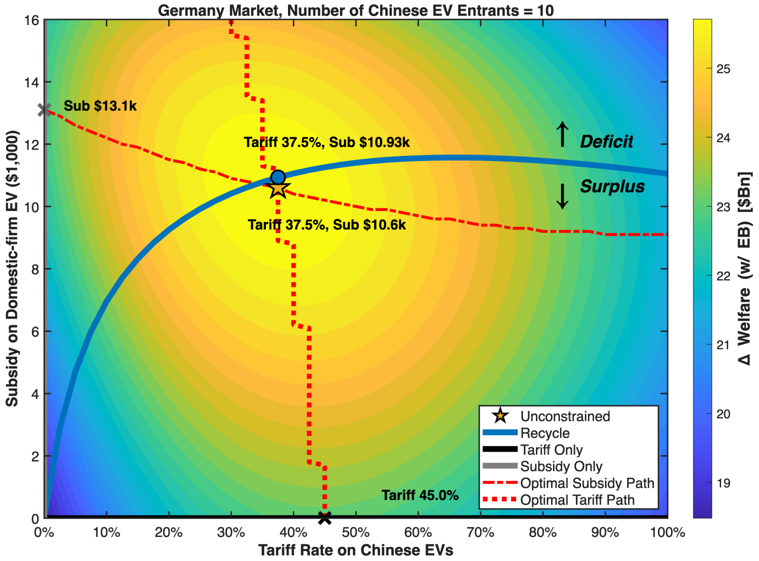
Notes: This figure shows the trends in EV adoption and the market penetration of China-manufactured EVs across major global markets from 2018 to 2024. Panel (a) displays the EV adoption rate, defined as the share of new EV registrations in total passenger vehicle sales. The lines represent the US, EU, 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: Optimal Policy Mix and Welfare Contour

(a) U.S. Market

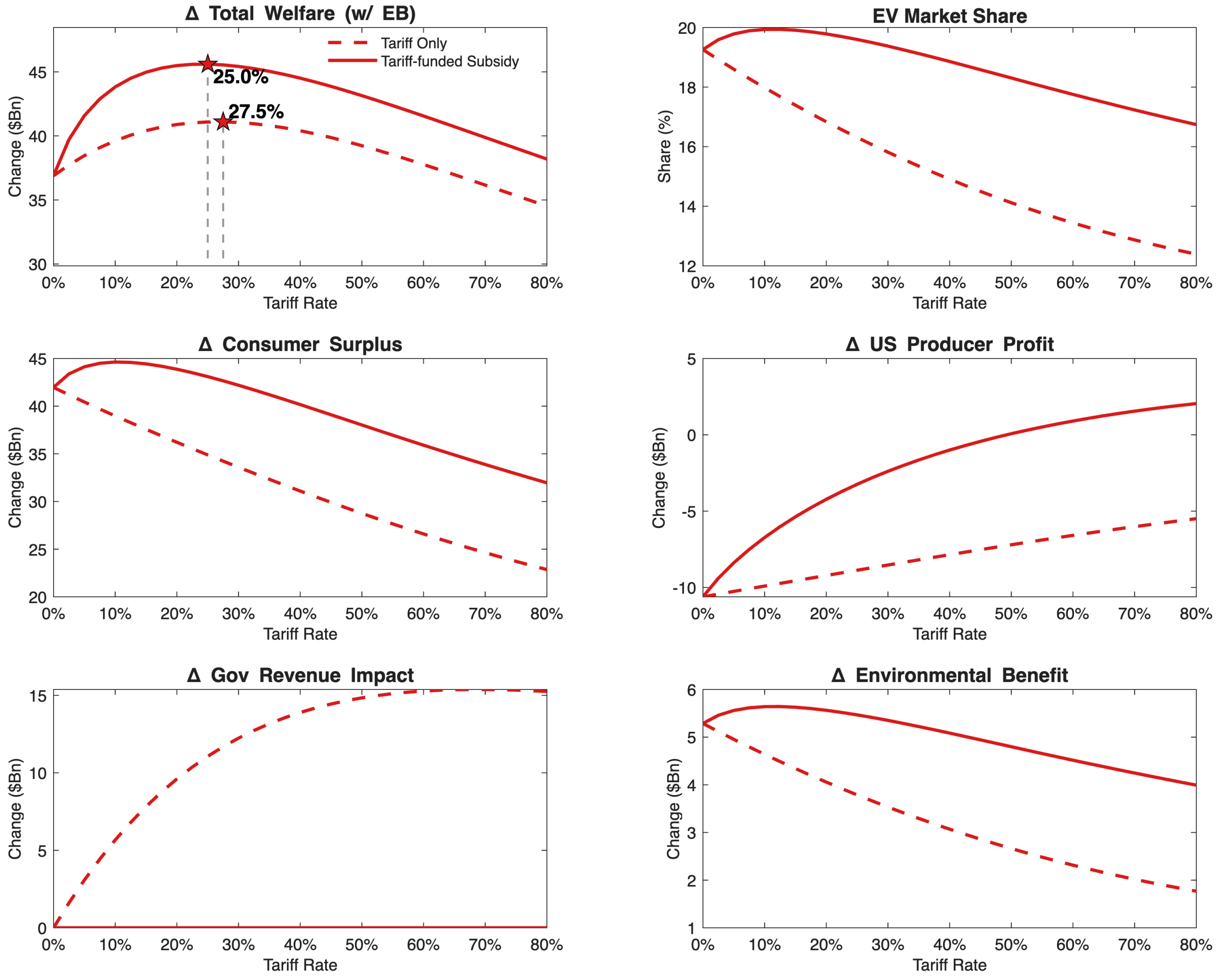


(b) Germany Market



Notes: This figure illustrates the simulated changes in social welfare (ΔWelfare) relative to the 2023 status quo across a two-dimensional policy space, following the introduction of the **top 10** Chinese-manufactured EV models into the US and Germany markets. 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 unconstrained optimum that maximizes total welfare. The blue solid line represents the tariff-recycling subsidy path, with the blue circle marking the optimal point along this constraint. Allocations above the blue line imply a fiscal deficit (subsidy outlays exceed tariff revenues); allocations below imply a fiscal surplus. The grey 'x' markers denote the optimal points under single-policy regimes (only subsidy and only tariff). 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.

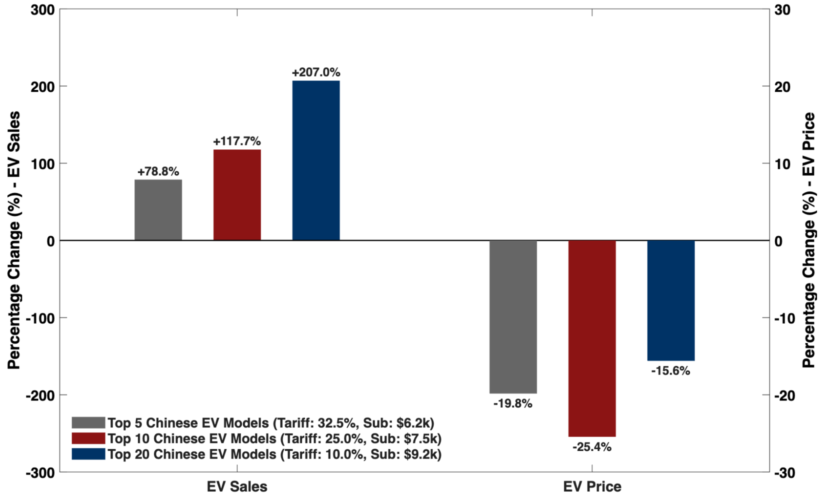
Figure 3: Decomposition of Welfare and Relationship with Tariff Rates



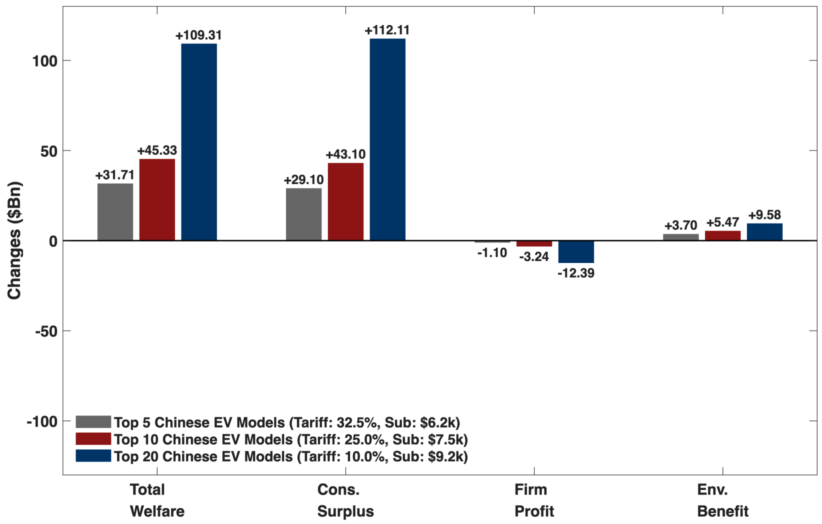
Notes: This figure illustrates the simulated changes in social welfare components and market outcomes relative to the 2023 status quo, following the introduction of the **top 10** Chinese-manufactured EV models into the US market. In each panel, the red solid line represents the scenario with tariff 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 4: Market Outcomes and Welfare Effects under Optimal Tariff-Funded Subsidies

(a) EV Adoption and EV Price



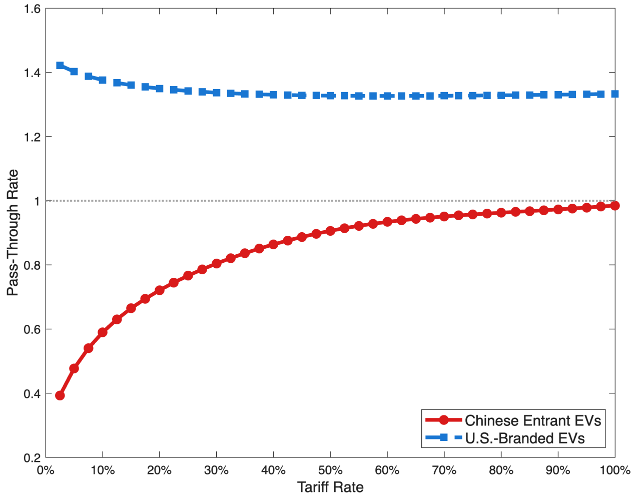
(b) Welfare



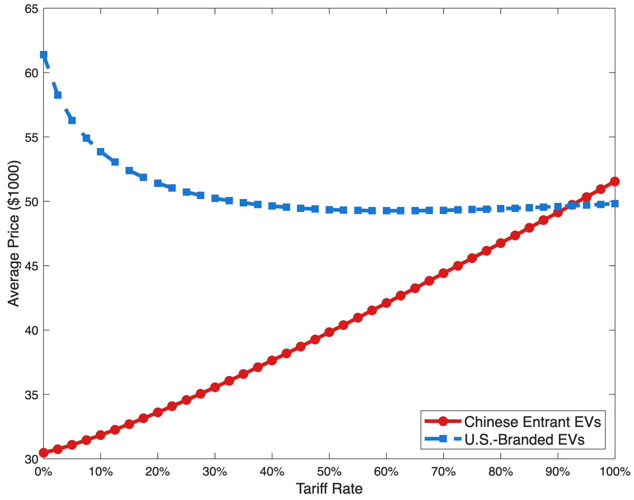
Notes: This figure shows market outcomes and welfare effects under the optimal tariff-recycling subsidy policies. All outcomes are reported relative to the 2023 status quo baseline. Panel (a) reports percentage changes in EV sales and the sales-weighted average EV price. The left set of bars shows the 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, comprising total welfare, consumer surplus, firm profits, and environmental benefits, in that order. Government revenue is not shown because the recycling design forces tariff revenue and subsidy expenditure to balance by construction, so the net fiscal flow is zero. 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). The same policy scenarios are associated with manufacturing job losses of 30.9k, 52.0k, and 107.6k, respectively, which are not shown in the figure.

Figure 5: Aggregated Pass-Through Rates and EV Price along with Tariff Rates

(a) Pass-Through Rates

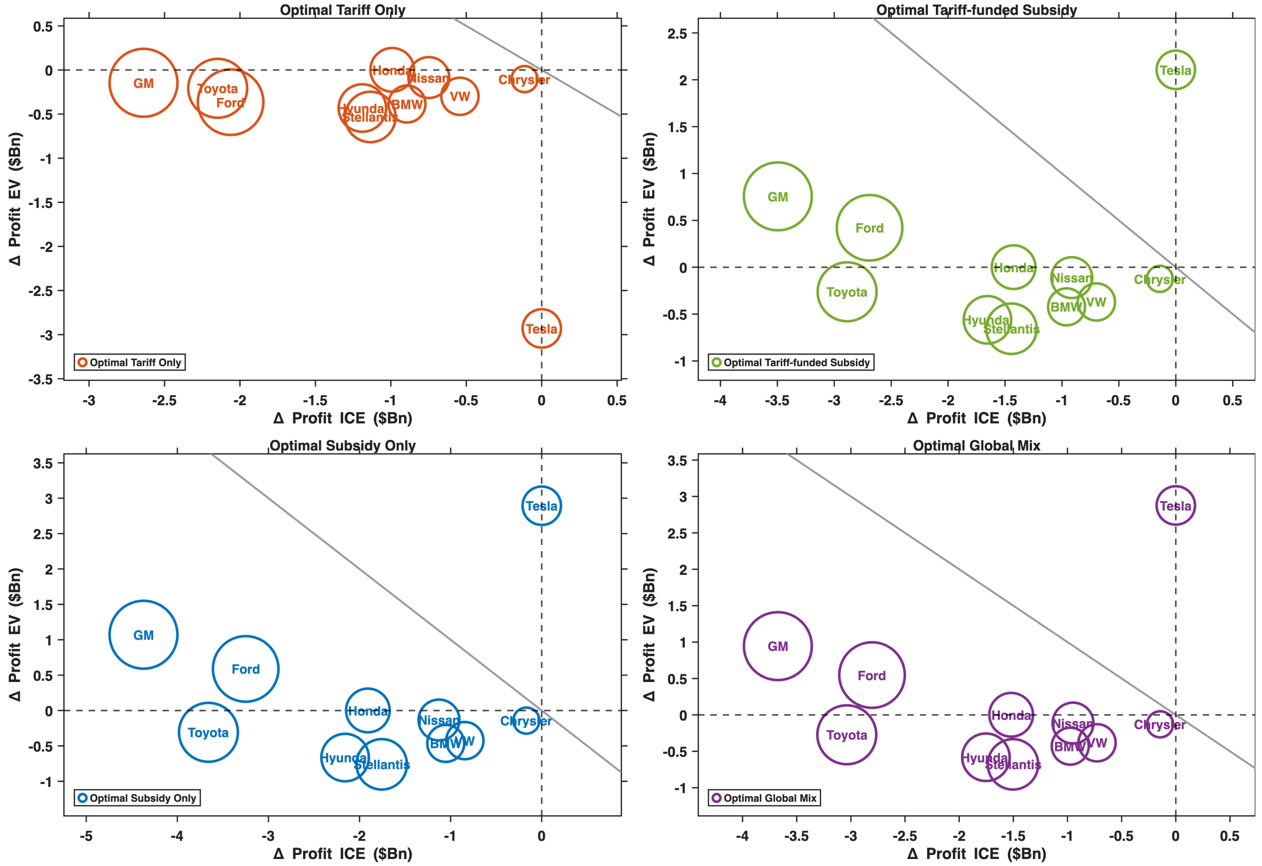


(b) Average EV Price



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 6: 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 optimal policy scenarios relative to the 2023 status quo: Optimal Tariff Only (top left), Optimal Tariff-funded Subsidy (top right), Optimal Subsidy Only (bottom left), and Unconstrained Optimum (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 all panels except Optimal Tariff Only, 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)		(2)		(3)		(4)	
	OLS		IV		RC		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) × 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 2023. 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 and Market Impacts of Chinese EV Entry under Alternative Policy Scenarios: United States

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ban		**Add top 10 China manufactured EV + Policy-relevant scenarios**				
	Baseline	*Subsidy*	*Baseline Tariff*	*Punitive Tariff*	*Draconian Tariff*	*Tariff Recycle*	*Subsidy*
Subsidy/Tariff		$7,500	2.5%	27.5%	102.5%	102.5%	$7,500
Panel (a) Effects on EV adoption							
Weighted Price: ICE ($1,000)	42.62	42.85	42.72	42.51	42.39	42.68	42.93
Weighted Price: Non-Chinese EV ($1,000)	53.18	43.14	53.59	52.44	51.79	40.81	41.53
Weighted Price: Chinese EV ($1,000)	0.00	0.00	33.95	38.99	56.72	57.16	32.94
Total Sales (1,000)	15,327	15,508	15,798	15,646	15,435	15,639	15,993
Total EV Sales (1,000)	1,380	2,029	2,990	2,513	1,786	2,475	3,562
EV Share (%)	9.00	13.08	18.92	16.06	11.57	15.83	22.27
Chinese EV % of total EV	0.00	0.00	69.00	58.78	30.56	19.34	56.61
Profit, CHN EV ($Bn)	0.00	0.00	27.92	17.01	5.49	4.94	26.91
Panel (b) Effects on US Welfare							
△ Welfare ($Bn)		5.64	37.48	40.88	30.78	34.59	42.48
△ Consumer Surplus ($Bn)		8.71	41.19	34.24	19.45	28.15	50.66
△ Government Revenue ($Bn)		-11.82	1.61	11.69	14.48	0.00	-9.30
△ Profits, All US firms ($Bn)		6.64	-10.44	-8.70	-4.49	2.92	-5.70
△ Profit, US EV		8.48	-4.66	-3.89	-1.93	7.22	1.59
△ Profit, US ICE		-1.84	-5.78	-4.82	-2.56	-4.30	-7.30
△ Env. Benefits ($Bn)		2.10	5.12	3.66	1.34	3.52	6.82
△ Mfg Jobs (Thousands)		7.16	-86.91	-62.80	-22.68	-11.25	-76.66
△ CO_2 Reduction (Mn tons)		36.73	89.34	63.88	23.37	61.47	119.04

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) reports the 2023 status quo (no Chinese EV entry, no domestic EV policy) as a reference baseline. Column (2) maintains the Chinese EV ban while providing a $7,500 subsidy to domestically manufactured EVs, mimicking the domestic-content requirement under the Inflation Reduction Act. Columns (3)–(7) lift the ban and introduce the top 10 Chinese EV models. Column (3) applies the baseline 2.5% WTO most-favored-nation (MFN) tariff. Column (4) mimics the 2018 Trump administration's Section 301 action, which imposed an additional 25% punitive tariff. Column (5) reflects the May 2024 Biden administration Section 301 update, raising the total tariff to 102.5%. Column (6) considers a hypothetical policy in which revenue from the 102.5% tariff is earmarked to fund domestic EV subsidies; the implied budget-balancing subsidy is approximately $8,139 per vehicle. Column (7) models a free-trade scenario combined with a $7,500 domestic EV subsidy under the Inflation Reduction Act. 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 distribution and market services is assumed to pertain to US domestic firms. All average numbers are calculated as sales-weighted averages across models. △ CO_2 Reduction reports the lifetime CO_2 reduction (in million tons).

Table 3: Welfare and Market Impacts of Chinese EV Trade Policies: European Union

	(1)	(2)	(3)	(4)	(5)
	Chinese EVs Present				**No Chinese EVs**
Additional Policy	*Benchmark* 10% MFN (2023)	*EU CVD* Brand-specific	*CVD+Recycle* Revenue recycled	*MPC* Price undertaking	*Remove CHN EVs* Counterfactual ban
Panel (a) Effects on EV adoption					
Weighted Price: ICE ($1,000)	46.05	46.04	46.07	46.04	46.07
Weighted Price: Non-Chinese EV ($1,000)	62.30	62.25	61.36	62.25	62.58
Weighted Price: Chinese EV ($1,000)	54.72	71.55	71.64	71.55	—
Total Sales (1,000)	9,850	9,822	9,839	9,822	9,795
Total EV Sales (1,000)	2,345	2,270	2,336	2,270	2,208
EV Share (%)	23.81	23.11	23.74	23.11	22.54
Chinese EV % of total EV	9.89	4.50	4.28	4.50	—
Profit, CHN EV ($Bn)		1.68	1.65	3.10	—
Panel (b) Effects on EU Welfare (change vs. Benchmark)					
△ Welfare ($Bn)		-0.11	1.23	-1.52	-5.00
△ Consumer Surplus ($Bn)		-2.22	-0.68	-2.22	-5.64
△ Government Revenue ($Bn)		1.41	0.00	0.00	-1.15
△ Profits, EU domestic firms ($Bn)		1.15	1.89	1.15	2.57
△ Profit, EU EV		0.65	1.87	0.65	1.56
△ Profit, EU ICE		0.50	0.02	0.50	1.01
△ Env. Benefits ($Bn)		-0.45	0.01	-0.45	-0.79

Notes: This table reports the market and welfare effects of import policies against Chinese EVs in the European Union. Results are aggregated across six EU member states: Austria, France, Germany, the Netherlands, Spain, and Sweden. The analysis works with existing Chinese EV models present in the 2023 EU data; no additional entrants are introduced in any scenario. Chinese-owned brands (including BYD, MG (SAIC), Aiways, and Geely-group brands such as Polestar, Volvo EVs, and Lotus EVs) are classified as Chinese for all counterfactual scenarios. Column (1) is the benchmark, reflecting the status quo in which Chinese EVs are present in the EU market under the existing 10% MFN tariff, embedded in 2023 observed prices. Column (2) applies the EU's October 2024 brand-specific countervailing duties (CVD) on top of the existing 10% MFN: BYD +17%, Geely group +18.8%, and all other Chinese brands +35.3%, applied to existing Chinese EV models only. Column (3) applies the same CVD tariffs as Column (2) and recycles the resulting revenue as a uniform per-vehicle subsidy to EU-member-manufactured EVs, with the budget-clearing subsidy solved jointly across all six member states. Column (4) models a Minimum Price Commitment (MPC), in which the price equilibrium is identical to Column (2) but the duty revenue accrues to the Chinese exporting firms rather than the EU government, consistent with a negotiated price floor arrangement. Column (5) is a counterfactual ban in which all existing Chinese EV models are removed from the EU market. Welfare is the sum of consumer surplus, profits of EU-headquartered automakers aggregated across the six member states, government revenue net of subsidy expenditure, and environmental benefits. The baseline year is 2023. All monetary values are in 2023 USD. All averages are sales-weighted.

Table 4: Welfare Effects under Optimal Policy Mixes: Adding **Top 10** Chinese EVs to the US Market, Year = 2023

	(1)	(2)	(3)	(4)	(5)
	Ban	**Add top 10 China manufactured EV + Optimal designs**			
	Benchmark	*Tariff Only*	*Subsidy Only*	*Both*	*Recycling*
Tariff/Subsidy		27.5% / \$0.00k	0.0% / \$9.60k	22.5% / \$8.40k	25.0% / \$7.47k
Panel (a) Effects on EV adoption					
Weighted Price: ICE (\$1,000)	42.62	42.51	43.05	42.81	42.74
Weighted Price: Non-Chinese EV (\$1,000)	53.18	52.44	37.87	39.75	41.24
Weighted Price: Chinese EV (\$1,000)	0.00	38.99	32.85	37.62	38.17
Total Sales (1,000)	15,327	15,646	16,079	15,882	15,834
Total EV Sales (1,000)	1,380	2,513	3,790	3,241	3,103
EV Share (%)	9.00	16.06	23.57	20.41	19.60
Chinese EV % of total EV	0.00	58.78	51.60	44.50	45.54
Profit, CHN EV (\$Bn)	0.00	17.01	25.95	16.73	16.20
Panel (b) Effects on US Welfare					
△ Welfare (\$Bn)		40.88	42.94	45.45	45.33
△ Consumer Surplus (\$Bn)		34.24	53.67	45.01	43.11
△ Government Revenue (\$Bn)		11.69	-14.77	-3.01	
△ Profits, All US firms (\$Bn)		-8.70	-3.41	-2.43	-3.24
△ Profit, US EV		-3.89	4.38	4.20	3.08
△ Profit, US ICE		-4.82	-7.79	-6.62	-6.32
△ Env. Benefits (\$Bn)		3.66	7.46	5.87	5.47
△ Mfg Jobs (Thousands)		-62.80	-69.94	-51.52	-51.95
△ CO_2 Reduction (Mn tons)		63.88	130.14	102.54	95.44

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) reports the optimal tariff, and Column (3) reports the optimal subsidy. Column (4) reports the unconstrained optimum, allowing both tariffs and subsidies. Column (5) 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. △ Mfg Jobs reports the change in manufacturing employment (in thousands), computed using industry input–output coefficients with a transplant-production ratio of 0.53. △ CO_2 Reduction reports the lifetime CO_2 reduction (in million tons), computed as the reduction in ICE vehicle sales multiplied by 78.5 tons of lifetime CO_2 per vehicle.

Table 5: Distributional Impacts of Chinese EV Entry to the US under Optimal Policy Mixes

	(1)	(2)	(3)	(4)	(5)
	Ban	**Add Top 10 China manufactured EV**			
	Benchmark	*Tariff Only*	*Subsidy Only*	*Both*	*Recycling*
Tariff/Subsidy		27.5% / $0.00k	0.0% / $9.60k	22.5% / $8.40k	25.0% / $7.47k
Panel (a) Effects on EV Share by Income Quantile					
EV Share (%) Q1	6.80	15.62	23.86	19.92	19.05
EV Share (%) Q2	7.56	12.41	19.98	16.93	16.04
EV Share (%) Q3	10.51	17.15	23.62	21.28	20.59
EV Share (%) Q4	11.15	19.06	26.82	23.51	22.71
Panel (b) Effects on Consumer Surplus by Income Quantile					
△ Consumer Surplus ($Bn) Q1		6.36	11.24	8.63	8.15
△ Consumer Surplus ($Bn) Q2		4.57	8.50	6.96	6.57
△ Consumer Surplus ($Bn) Q3		12.85	17.76	15.61	15.12
△ Consumer Surplus ($Bn) Q4		10.45	16.16	13.81	13.26

Notes: This table reports the distributional impact 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) reports the optimal tariff, and Column (3) reports the optimal subsidy. Column (4) reports the unconstrained optimum, allowing both tariffs and subsidies. Column (5) 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. Q1 to Q4 are income quantiles, where Q4 represents the wealthiest consumers.

Table 6: Optimal Policy Across Markets: United States, Germany, United Kingdom, and Spain

Policy Scenario	**United States**	**Germany**	**United Kingdom**	**Spain**
Tariff Only				
Tariff Rate	27.5%	45.0%	20.0%	17.5%
Subsidy ($1,000)	0.00	0.00	0.00	0.00
ΔW^{EB} ($Bn)	41.09	23.16	9.80	8.23
Subsidy Only				
Tariff Rate	0.0%	0.0%	0.0%	0.0%
Subsidy ($1,000)	9.60	13.10	13.40	0.00
ΔW^{EB} ($Bn)	43.26	22.86	9.60	7.95
Unconstrained Optimum				
Tariff Rate	22.5%	37.5%	20.0%	17.5%
Subsidy ($1,000)	8.40	10.60	12.80	0.00
ΔW^{EB} ($Bn)	45.72	25.95	10.04	8.23
Tariff-funded Subsidy				
Tariff Rate	25.0%	37.5%	12.5%	17.5%
Subsidy ($1,000)	7.47	10.93	16.02	0.00
ΔW^{EB} ($Bn)	45.60	25.94	9.94	8.23
# Domestic EV Models	16	61	8	0
Avg Domestic EV Markup ($1,000)	16.65	23.67	30.11	—

Notes. This table reports the optimal policy parameters across four markets under a common entry scenario of $N = 10$ Chinese EV models. The four row panels correspond to distinct policy scenarios. *Tariff Only* fixes the subsidy at zero and optimizes over the tariff rate; *Subsidy Only* fixes the tariff at zero and optimizes over the subsidy; *Unconstrained Optimum* optimizes the two instruments jointly; *Tariff-funded Subsidy* restricts attention to the budget-balanced recycling path, along which tariff revenue collected on Chinese imports is rebated as a per-unit subsidy to domestic EVs. Within each panel, ΔW^{EB} denotes the change in total welfare inclusive of environmental benefits, measured in billions of U.S. dollars relative to the status quo baseline. The policy grid uses tariff increments of 2.5 percentage points and subsidy increments of $100. The last two rows report status-quo market characteristics: *# Domestic EV Models* is the count of EV models from domestically-headquartered brands, and *Avg Domestic EV Markup* is their sales-weighted average markup (price less marginal cost, in thousands of U.S. dollars). Spain hosts no domestically-headquartered EV brand, so the optimal subsidy is zero across all policy regimes; the welfare gains from tariffs alone reflect the pure profit-shifting motive.

Online Appendix

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

Panle Jia Barwick   Jack Collison   Penny Goldberg   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 b for simplicity. Rearranging the first-order condition for τ:

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

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.

$\square$

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 b:

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

Denominator. Because a subsidy reduces domestic marginal cost, it unambiguously expands domestic output ($dQ_j/db > 0$ 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 b 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 $b < 0$ 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.

$\square$

Lemma 1. *Under a balanced budget constraint, we have sign*$(1-\lambda) =$ *sign*(G^*)*, where* G^* *is the value of the government budget for the unconstrained planner. Equivalently,* $\lambda < 1$ *if* $G^* > 0$*,* $\lambda = 1$ *if* $G^* = 0$*, and* $\lambda > 1$ *if* $G^* < 0$*.*

Proof. Define $f(0) = W(\gamma_c^*)$, where γ_c^* are the constrained welfare-maximizing policies. Analogously, define $f(G^*) = W(\gamma^*)$ where G^* is the government budget under the unconstrained optimal policies γ^*. Notice that $f(0) \leq f(G^*)$ with equality if $G^* = 0$, meaning G^* maximizes f. Under regularity assumptions (smoothness, unique interior solution for the unconstrained planner), f is

C^1 with a unique interior maximum at G^*, meaning we have $f'(0) > 0$ for $G^* > 0$ and $f'(0) < 0$ for $G^* < 0$. By the envelope theorem, $1 - \lambda = f'(0)$. This implies that $\text{sign}(1-\lambda) = \text{sign}(G^*)$, completing the proof.

□

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 b 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). From Lemma (1), this occurs when $G^* > 0$, i.e., the constrained planner is forced to a lower government surplus than they would like, distorting the optimal policies.

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). From Lemma (1), this occurs when $G^* < 0$, i.e., the constrained planner is forced to a higher government surplus than they would otherwise like, distorting the optimal policies.

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 ($\frac{d^2W}{d\tau db} > 0$) 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 ($\frac{d^2W}{d\tau db} < 0$): (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 $\frac{d^2W}{d\tau db} > 0$ and substitutes when $\frac{d^2W}{d\tau db} < 0$. We differentiate $dW/d\tau$ with respect to b. The cross-partial then decomposes into three channels:

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

Second-order effects The term $\partial^2\tilde{P}_j/\partial\tau\,\partial b$ 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 ($\partial\tilde{P}_j/\partial b < 0$ 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 $dQ_j/db > 0$ 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 ($dQ_j/db < 0$ for $j \in J_f$), shrinking the import demand base that generates tariff revenue and making the term $\sum_{j\in J_f}(\partial P_j/\partial b\, Q_j + P_j\, dQ_j/db)$ 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, $\frac{d^2W}{d\tau db} > 0$ 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:

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

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 $\partial P/\partial b \to 0$ 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.

$\square$

A.1 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:

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

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 and a unit subsidy b on domestic goods.

Optimal Policy Mix Figure E.1 compares four scenarios: (i) unconstrained use of both tariffs τ and subsidies b, (ii) tariff τ only ($b = 0$), (iii) subsidy b 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.[1] 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

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[1] 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.

government budget constraint merely transfers tariff revenue to the subsidy, leaving the planner free to choose a (τ^*, b^*) that is mostly unaffected.[2]

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.[3] Figure E.2 reinforces this by displaying the iso-welfare curves in (τ, b) space.

Figure E.3 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 E.1. 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 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.

Market Structure Figure E.17 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 $b = 0$, 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

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[2] 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.

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

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 b. 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 b^* 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 E.12 varies the import mean utility δ_f relative to the domestic baseline $\delta_d = 1$, tracing out the optimal policies τ^*, b^* 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 b^* 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 E.18 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.

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.

B Derivations and Formulas

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

The profit function for exporter is,

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

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,

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

B.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

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

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

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

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

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

Let

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

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

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

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, distinguish between the effective-price markup $m(p)$ and the tax-exclusive markup μ. Since

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

the effective-price markup is

$$m(p) \equiv p - (1+\tau)c = (1+\tau)\mu.$$

The firm's first-order condition implies

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

so that the pricing equation under an ad valorem tariff can be written as

$$p = (1+\tau)c + m(p).$$

Comparing this expression with

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

implies that the tax-exclusive markup is

$$\mu = \frac{m(p)}{1+\tau}.$$

Differentiating $m(p)$ with respect to price gives

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

Thus, defining demand curvature as

$$\rho \equiv \frac{s\,s_{pp}}{(s_p)^2},$$

we have

$$\frac{dm}{dp} = \rho - 1.$$

Along the tariff path,

$$\frac{dm}{d\tau} = \frac{dm}{dp}\frac{dp}{d\tau} = (\rho - 1)\frac{dp}{d\tau}.$$

Now differentiate the relationship $\mu = m/(1+\tau)$ with respect to τ:

$$\mu' \equiv \frac{d\mu}{d\tau} = \frac{1}{1+\tau}\frac{dm}{d\tau} - \frac{m}{(1+\tau)^2}.$$

Using $m = (1+\tau)\mu$, this becomes

$$\mu' = -\frac{\mu}{1+\tau} + \frac{\rho - 1}{1+\tau}\frac{dp}{d\tau}.$$

Substituting this expression into Equation C.18 and rearranging yields

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

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

C Additional Details on Background, Data, and Variable Construction

C.1 Cross-Market Policy Stances on Chinese EVs

This appendix provides detailed policy descriptions of the four destination markets summarized in Section 3.

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 the 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. The rule states that it is motivated by complex vehicle hardware and software that are not reviewed by the US, and are thus potential risks to US national security. In the public discourse and comments on the rule, major automakers (especially large US firms) support the rule, but took steps to ensure that their own supply chains will not be disrupted by commenting on the specific vehicle components subject to the rule. 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 adopted a similarly restrictive stance through the end of 2025. It imposed a 100 percent surtax on Chinese-made EVs, which, combined with the standard 6.1 percent MFN tariff, raised 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 EU 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 EU more open than the US and Canada. Figure 1 shows that the share of China-manufactured EVs in the EU 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.

C.2 Construction of Mean Utility and Marginal Cost for Introduced Models

When we introduce a set of Chinese EV models into the US market in our counterfactual analysis, we need to take a stance on consumers' mean utility for those models and on their marginal cost of supplying the US market. This appendix subsection describes how we construct both objects.

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.[4] 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

$$\delta_{j,\text{US}} = \mathbf{X}_{j,\text{US}}\bar{\beta} + \eta_{j,\text{US}} + \xi_{j,\text{US}}, \qquad j \in \mathscr{F}^{\text{CN}}, \tag{C.20}$$

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:

$$\eta_{j,\text{US}} = \eta_{j,\text{China}} + \kappa_{g(j)}. \tag{C.21}$$

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

$$\kappa_g = \mathbb{E}\Big[\eta_{j',\text{US}} - \eta_{j',\text{China}} \mid g(j') = g,\ j' \in \mathscr{J}^{\text{obs}}\Big], \quad g \in \{\text{EV}, \text{ICE}, \text{HV}, \text{PHEV}\}. \tag{C.22}$$

This construction implies that the mean utility of an entering Chinese EV in the US inherits its

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[4] 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.

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.[5]

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.

Marginal Cost. 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.[6] 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 there, we observe a set of Chinese EV makes and models that are sold in both China and the European countries in our sample. We use the estimated cross-country marginal-cost gap for these overlapping models (i.e., Chinese EVs sold in both China and Europe) to discipline the marginal-cost level of the counterfactually introduced Chinese models in the US market, accounting for tariffs and other per-vehicle trade costs. The assumption is that the observed cost wedge between serving Europe and China 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, consistent with industry benchmarks and practitioner estimates of shipping and downstream selling costs in the global automobile market.

C.3 Calibration of Environmental Benefits

Following Funke et al. (2023), we calibrate the per-vehicle lifetime external costs in equation (10) as $\text{UnitCarbCost} = \$3{,}810$ (climate damages from CO_2 emissions) and $\text{UnitHealthCost} = \$687$

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[5] 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: we use the distribution of estimated fixed effects in the observed US market to impute $\eta_{j,\text{US}}$ for entering Chinese EVs, assigning $\eta_{j,\text{US}}$ 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.

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

(health damages from local air pollution) for the US. To also characterize the climate impact in physical units, we report the lifetime CO_2 reduction as $\Delta CO_2 = -\Delta Q^{\text{ICE}} \times 78.5$ tons, where 78.5 tons of lifetime CO_2 per vehicle is implied by UnitCarbCost evaluated at the social cost of carbon of approximately $48.5 per ton.

C.4 Construction of Manufacturing Job Changes and Job Values

Step 1: Mapping Equilibrium Sales to Domestic Jobs. 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% (Source: Alliance for Automotive Innovation). 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 $\kappa^{\text{ICE}} = 0.10$ jobs per vehicle, calculated as payroll employment in motor vehicles and parts (approximately 1 million jobs; FRED, CES3133600101) divided by US light-vehicle production in 2023 (approximately 10 million units; FRED, MVAAUTLTTS). We assume EV assembly to be less labor-intensive by scaling the ICE coefficient by 0.70, i.e., $\kappa^{\text{EV}} = 0.70 \times \kappa^{\text{ICE}}$, as suggested by Weng et al. (2024). The implied level of US manufacturing employment is

$$\text{Jobs} \ = \ \rho^{US}\Big(\kappa^{\text{ICE}}\, Q^{US,\text{ICE}} + \kappa^{\text{EV}}\, Q^{US,\text{EV}}\Big) + \rho^{TP}\Big(\kappa^{\text{ICE}}\, Q^{TP,\text{ICE}} + \kappa^{\text{EV}}\, Q^{TP,\text{EV}}\Big), \qquad \text{(C.23)}$$

where $\rho^{US} = 0.75$ and $\rho^{TP} = 0.53$ are the domestic-production shares, and $Q^{g,v}$ denotes total US sales of powertrain type $v \in \{\text{ICE}, \text{EV}\}$ by producer group $g \in \{US, TP\}$. The counterfactual change in employment relative to the 2023 status quo is

$$\Delta\text{Jobs} \ = \ \text{Jobs}^{\text{CF}} - \text{Jobs}^{\text{SQ}}. \qquad \text{(C.24)}$$

As an extension, we construct a back-of-the-envelope estimate of the net downstream US service-sector jobs created by Chinese EV entry. The key insight is that service-job creation depends on *total market expansion*—the increase in the number of consumers who purchase any vehicle—rather than on Chinese EV sales per se. A consumer who switches from a domestic vehicle to a Chinese EV simply reallocates dealership and service activity across manufacturers; the associated service jobs are neither created nor destroyed in net terms. Only buyers drawn from the outside option (those who would not have purchased a new vehicle absent Chinese EV entry) generate genuinely new downstream employment. We therefore apply the service-job coefficient to ΔQ^{total}, the simulation-implied increase in total new-vehicle sales relative to the ban scenario, rather than to Chinese EV sales.

The coefficient is calibrated from the 2024 NADA Annual Financial Profile of America's Franchised New-Car Dealerships, which reports 1.13 million franchised dealership employees supporting 15.9 million new light-vehicle sales, implying a raw coefficient of $1{,}130{,}000/15{,}900 \approx 71.1$ jobs per 1,000 vehicles sold. Since dealership employees serve new vehicle sales, used vehicle sales, and after-sales service simultaneously, we scale by the new-vehicle department's share of total dealership revenue (54.7%, per NADA 2024), yielding a coefficient of $71.1 \times 0.547 \approx 39 \approx 40$ jobs per 1,000 new vehicles sold. This is internally consistent with the manufacturing-job coefficient ($\kappa^{\text{EV}} = 0.07$ jobs per vehicle, i.e., 70 per 1,000), which is also derived from an aggregate employment-to-sales ratio and covers only NAICS 336 manufacturing—no dealership employment included.

Step 2: Monetizing the Social Value of Jobs. Worker wages enter as costs in firm revenue and are already netted out of $\Delta\Pi^{US}$ in equation (8), so adding a job-value term does not double-count wage income. It instead captures the additional social value of manufacturing employment beyond what firm profits record: unemployment frictions, agglomeration spillovers, local fiscal effects, and workers' valuation of job stability. The generalized welfare measure under a per-job-year value w is

$$\Delta\text{Welfare}^{\text{Job}}(w) \;=\; \Delta\text{Welfare}^{\text{EB}} \;+\; w \cdot \Delta\text{Jobs}, \tag{C.25}$$

with $\Delta\text{Welfare}^{\text{EB}}$ defined in equations (8)–(10). The main text uses two anchors that span the empirically defensible range. The lower bound $w_{\text{LB}} = \$10{,}700$/job-year is the revealed-preference value implied by US state and local subsidy auctions (Slattery, 2025). The upper bound $w_{\text{UB}} = \$70{,}000$/job-year is the average BLS NAICS 336 auto-manufacturing wage; because wages are largely a transfer between workers and employers (Bartik, 2015), this treats the wage as if it were all social cost and is therefore a conservative cap. Appendix Table F.5 adds three intermediate benchmarks: the Bartik (2015) welfare-theoretic displacement cost of \$12,250/job-year (17.5% of annual earnings at average unemployment and a 7% discount rate); that same value scaled by the Moretti (2010) local-employment multiplier of $1 + 1.6 = 2.6$, yielding \$31,850/job-year and capturing local-services spillovers; and the Allcott et al. (2026) fiscal cost of \$169,000 per additional US auto-manufacturing job under the IRA EV credits, a cost-effectiveness ratio included as an upper-extreme stress test. The qualitative ranking of policies is preserved across all five benchmarks.

C.5 Construction of the MCPF-Adjusted Welfare Measure

The welfare aggregator in equation (8) treats fiscal flows symmetrically: tariff revenue is added at par and subsidy expenditure is subtracted at par. This abstracts from the deadweight cost of raising the marginal dollar of tax revenue used to finance a subsidy. To accommodate this concern we report a robustness measure that applies a marginal-cost-of-public-funds (MCPF) penalty to the net fiscal deficit only:

$$\Delta\text{Welfare}^{\text{MCPF}}(\chi) \;=\; \Delta\text{Welfare}^{\text{EB}} \;-\; (\chi - 1)\cdot\max\{\text{Gov. Deficit}, 0\}, \tag{C.26}$$

where $\chi \geq 1$ is the MCPF multiplier. The max operator retains only positive net deficits: a deficit-financed dollar of subsidy costs χ dollars of social welfare, while a fiscal surplus (tariff revenue in excess of subsidy outlays) is assumed to be rebated lump-sum at par and so generates no additional distortion.

Appendix Table F.5 reports MCPF welfare for three multipliers, $\chi \in \{1.1, 1.3, 1.5\}$. The central value $\chi = 1.3$ is the canonical estimate from Ballard, Shoven, and Whalley (1985), who use a computable general-equilibrium model of the US to compute the marginal welfare cost of raising an additional dollar of revenue through the US tax system. The wider range $\chi \in [1.1, 1.5]$ brackets the empirical literature surveyed in Dahlby (2008) and reflects the substantial gap between partial- and general-equilibrium estimates of the marginal excess burden documented in Goulder and Williams (2003) as well as the range of taxable-income-elasticity estimates summarized in Saez, Slemrod, and Giertz (2012). In our counterfactuals the MCPF penalty binds under regimes that run a positive fiscal deficit at the optimum: specifically, the *Subsidy Only* regime (which has zero tariff revenue) and the joint *Unconstrained Optimum* ("Both"), whose optimal subsidy exceeds the tariff revenue raised. It does not bind under *Tariff Only*, which runs a fiscal surplus, nor under *Recycling*, where the budget-balancing constraint forces $\max\{\text{Gov. Deficit}, 0\} \approx 0$ by construction, so the welfare ranking of the recycling policy is invariant to χ.

D Empirical Estimates of the October 2024 EU Countervailing Duty

Our demand and supply parameters are estimated on data through 2023, whereas the EU's brand-specific countervailing duties (CVD) on China-manufactured electric vehicles took provisional effect on 5 July 2024 and were adopted definitively on 29 October 2024. The 2024–2025 post-policy period therefore provides a genuine out-of-sample test of the counterfactual predictions in Table 3: no observation from 2024 or 2025 enters the estimation at any stage. This appendix compares those predictions with the realized data.

Design. We use monthly new-registration data from MarkLines for the six EU member states in our sample (Austria, France, Germany, the Netherlands, Spain, and Sweden), by brand and model, from 2023m1 through 2025m12, restricted to battery-electric and plug-in-hybrid vehicles. The treated unit is the aggregate monthly EU-6 sales of incumbent models (those with at least six months of positive 2023 sales) of the five large mature Chinese brands established in the EU by 2023: BYD, MG (SAIC), Polestar (Geely), NIO, and Lynk & Co (Geely). Restricting to incumbent models mirrors the static 2023 product set underlying the structural counterfactual (Section 5), and the outcome is the log of aggregate monthly sales. Following Abadie, Diamond, and Hainmueller (2010), the synthetic control is a convex combination of non-Chinese EU-6 EV+PHEV donor brands chosen to minimize the squared pre-period (2023m1–2024m6) deviation between treated and synthetic log-sales; the donor pool is screened to brands whose own placebo pre-period RMSPE does not exceed twice the treated unit's. The resulting pool contains 27 brands, the treated-unit pre-period log-RMSPE is 0.166, and the fitted weights concentrate on Volkswagen (70.3%), Fiat (24.0%), and BMW (5.7%).

Result. Appendix Figure E.8 reports the event study. The pre-period gap is flat (log-RMSPE 0.166). After the provisional CVD takes effect, the treated-versus-synthetic gap drops sharply and stabilizes near the model's prediction; over the definitive-CVD window the mean gap is -0.853, a 57.4% reduction in the sales of these five brands. The apples-to-apples model benchmark, the implied log change in Chinese-brand sales of $\log(102.2/231.9) = -0.820$ (-56.0%) computed from Columns 1 and 2 of Table 3, lies within 1.4 percentage points.[7] The empirically estimated contraction thus lines up closely with the model-simulated estimate, indicating that the demand curvature and pass-through structure underlying our counterfactuals carry predictive content out of

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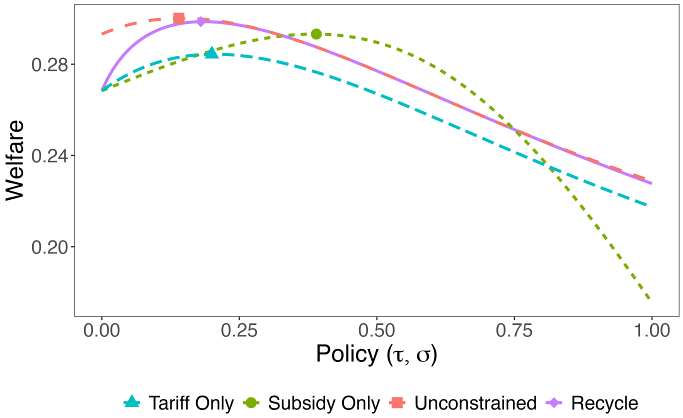
[7] The model's predicted log change in *share* is $\log(4.50/9.89) = -0.787$; the sales benchmark is marginally lower because the model also predicts a 3.2% contraction in the total EU EV market. Averaging instead over all CVD-active months from July 2024 (including the three provisional months) gives -0.798 (-55.0%).

sample.

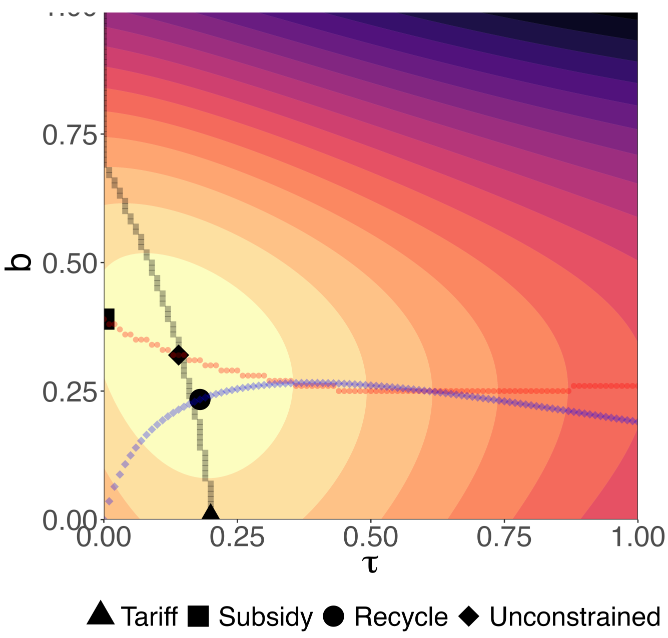
E Appendix Figures

Figure E.1: Welfare by Policy Mix



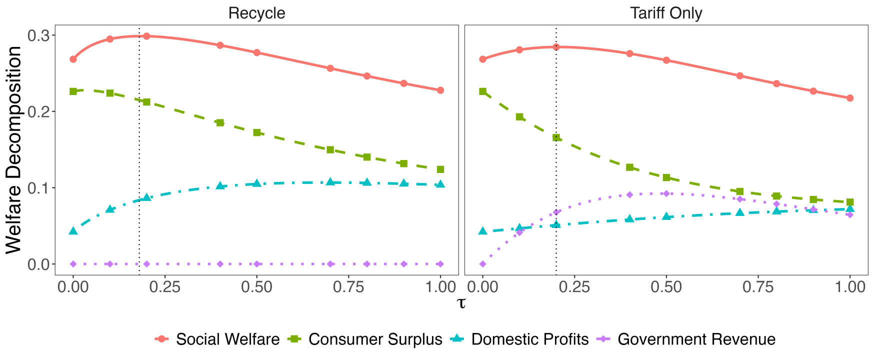
Notes: This figure shows optimal policies in the baseline simulation environment with $N_f = 5$. There are four scenarios: (i) unconstrained tariffs and subsidies (Both, dot); (ii) tariffs only (Tariff Only, cross); (iii) subsidies only (Subsidy Only, square); and (iv) revenue recycling (Recycle, triangle). 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 E.2: 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.

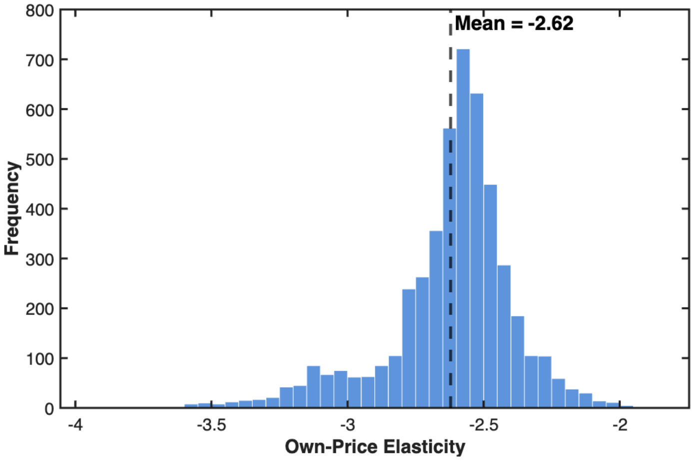
Figure E.3: Welfare Decomposition



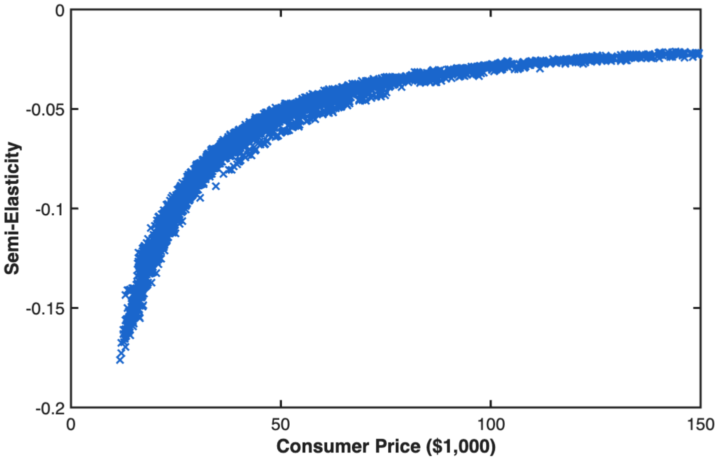
Notes: This figure decomposes the sources of welfare in the baseline simulation environment with $N_f = 15$. The left panel is the unconstrained planner, and the right panel is the revenue recycling (budget-constrained) planner. The y-axis is the welfare level, and the x-axis is the fixed tariff rate. 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 E.4: Estimated Own-Price Elasticity and Cross-Price Semi-Elasticity

(a) Estimated Own-price Elasticity

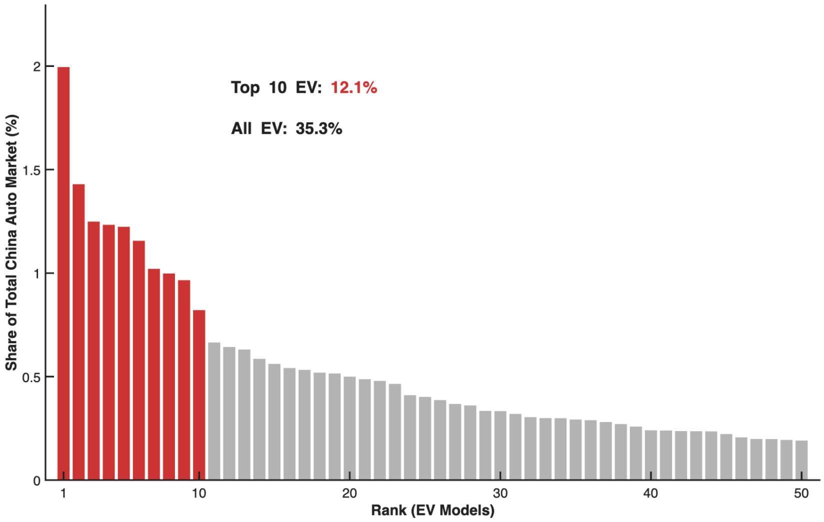


(b) Estimated Semi-Elasticity



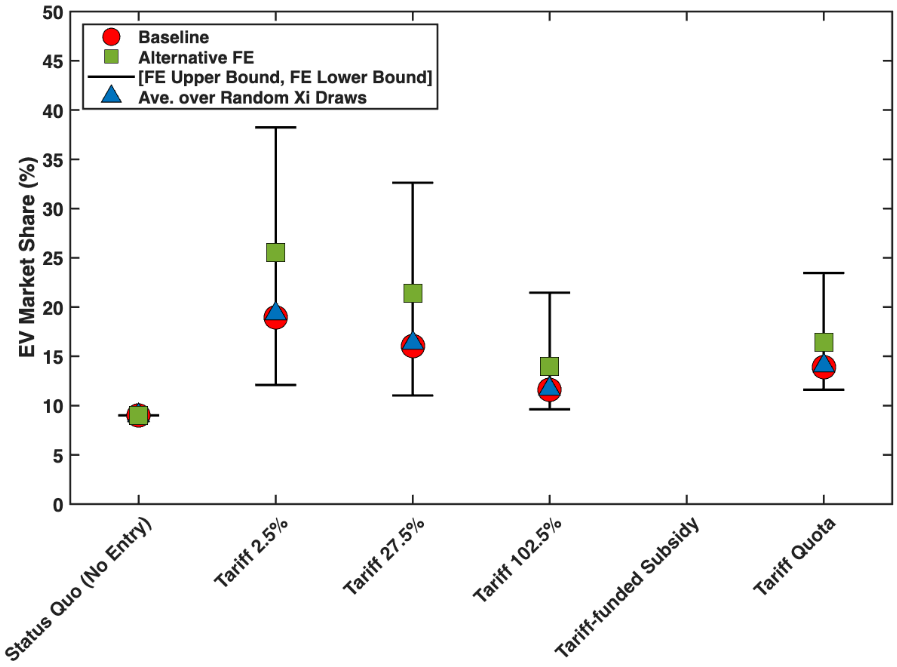
Notes: This figure displays the estimated demand elasticities. Panel (a) displays a histogram of the estimated own-price elasticities for all vehicle models in the sample, where the vertical dashed line indicates a mean elasticity of -2.62. Panel (b) illustrates the cross-price semi-elasticity between 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 E.5: Market Share Rank of Top Chinese EV Models in the Chinese Market



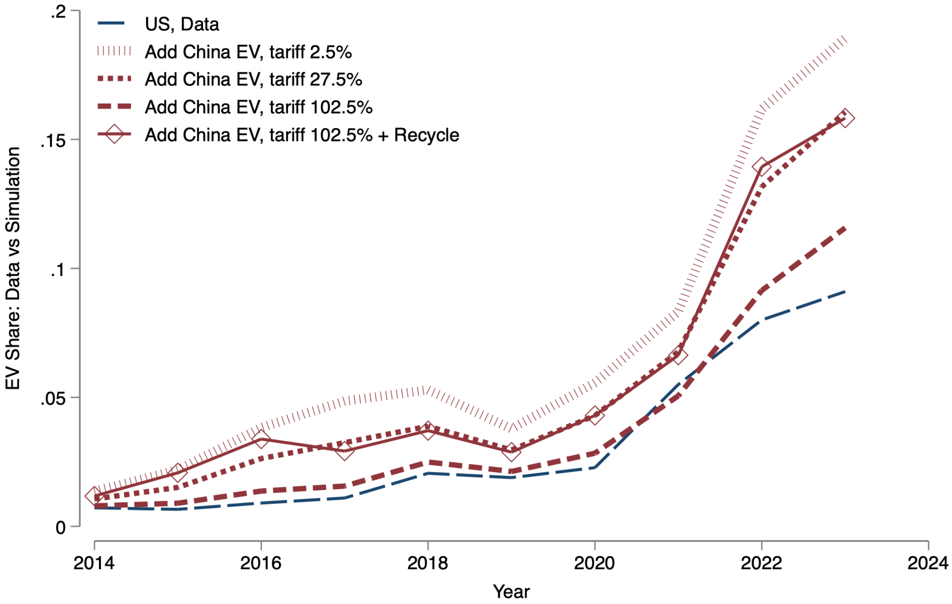
Notes: This figure illustrates the market share distribution of electric vehicle (EV) models in the Chinese domestic market based on 2023 data. The horizontal axis ranks individual EV models by their market share. The vertical axis represents each model's share of the total China auto market. The red 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 E.6: Robustness Using Alternative Fixed Effects and ξ draws, N. of Chinese EV = **10**



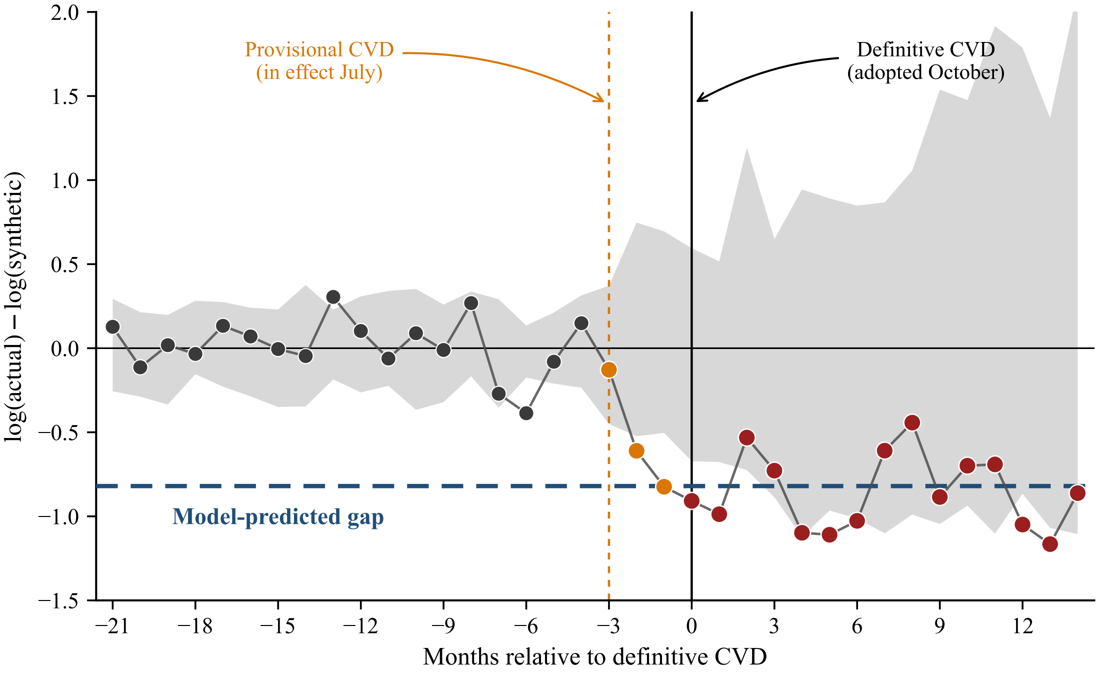
Notes: This figure presents a series of robustness checks for the simulated US EV market share in 2023 across various policy scenarios, serving as a sensitivity analysis for the results presented in Table 2. The simulation results are evaluated against two primary dimensions of uncertainty: the choice 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 E.7: 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.

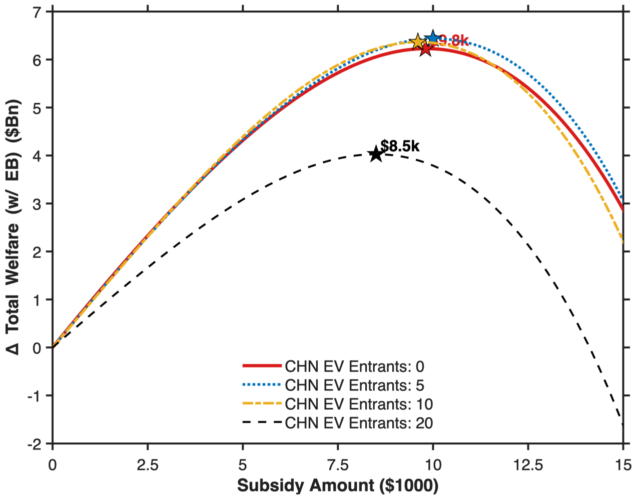
Figure E.8: Synthetic-Control Event Study of the October 2024 EU CVD on Incumbent Chinese-Brand EV Sales



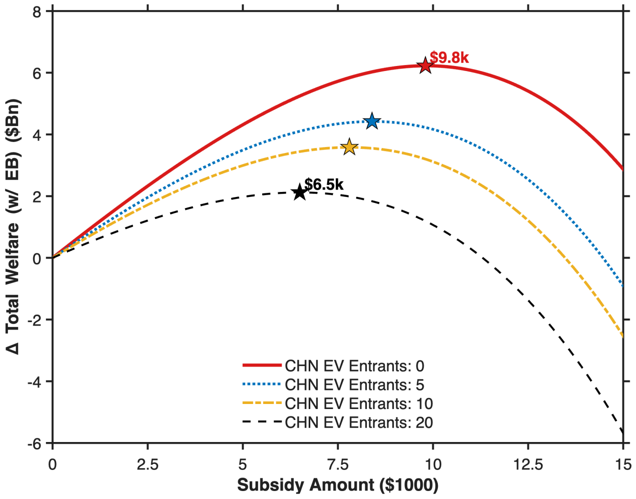
Notes: The plotted series is the log difference between actual and synthetic incumbent Chinese-brand EV+PHEV sales in EU-6 (Austria, France, Germany, the Netherlands, Spain, and Sweden), at monthly frequency from 2023m1 to 2025m12. The treated unit aggregates incumbent models (those with at least six months of positive 2023 sales) of five mature Chinese brands established in the EU by 2023: BYD, MG (SAIC), Polestar (Geely), NIO, and Lynk & Co (Geely). Gray circles denote pre-policy months, orange circles the three provisional-CVD months (July–September 2024), and red circles the definitive-CVD months (from October 2024). The shaded band is the 5th–95th percentile of placebo gaps obtained by running the same synthetic-control procedure with each donor brand as a fake-treated unit. The bold dashed line is the model-implied log change in Chinese-brand sales, $\log(102.2/231.9) = -0.820$ (-56.0% in levels), computed from Table 3 (Column 1 baseline: $0.0989 \times 2{,}345 = 231.9$ thousand; Column 2 post-CVD: $0.0450 \times 2{,}270 = 102.2$ thousand). The mean treated gap over the definitive window ($k \geq 0$) is -0.853 (-57.4% in levels). Data: MarkLines monthly sales.

Figure E.9: Optimal Domestic EV Subsidy under Varying Tariff Rates and Market Entry

(a) Tariff = 0%

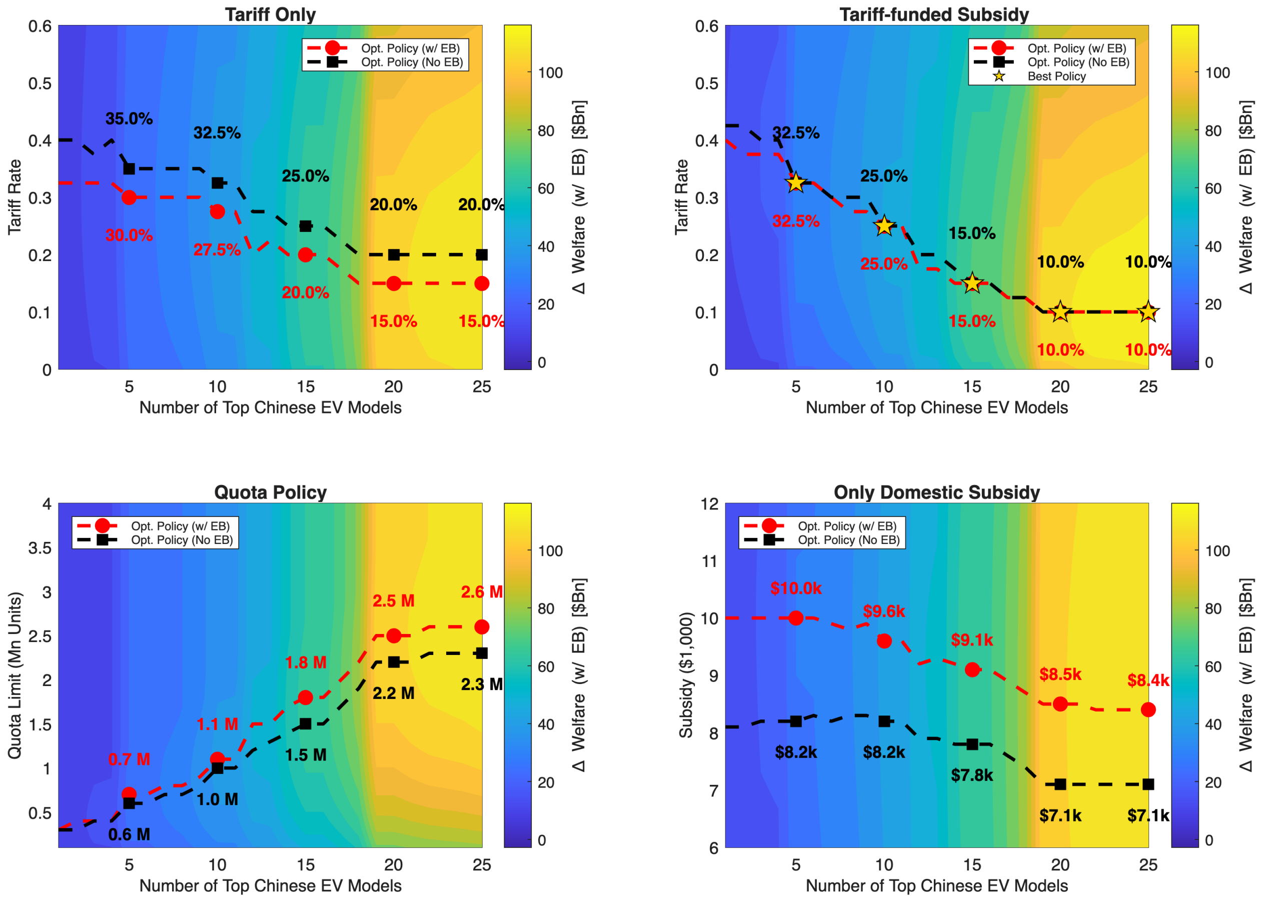


(b) Tariff = 100%



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.

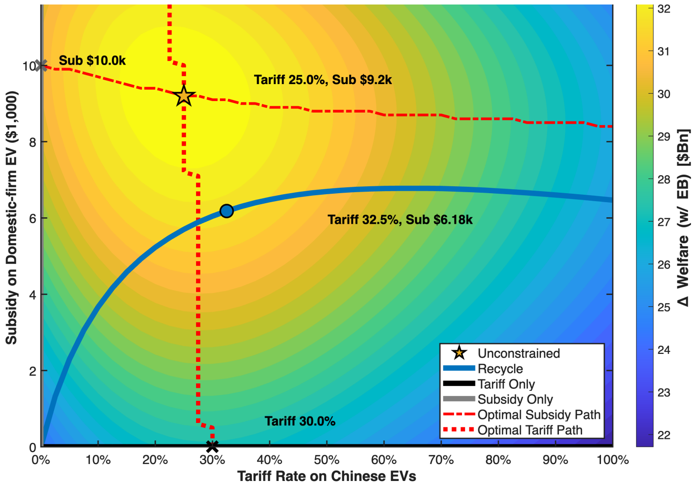
Figure E.10: Optimal Policy Design by Alternative Policy Regimes and Number of Entrants



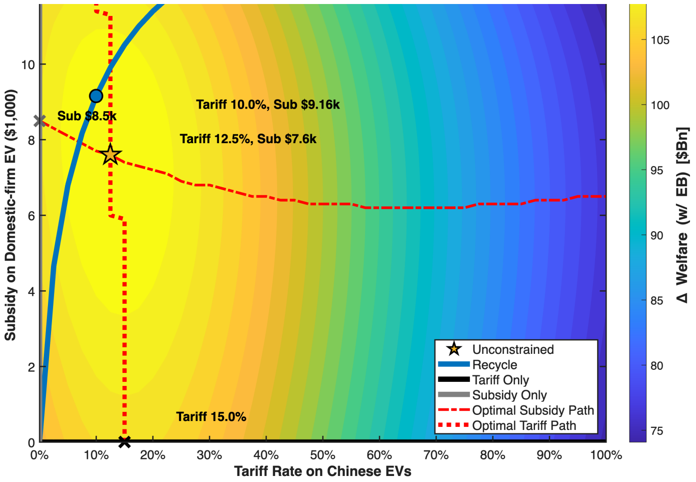
Notes: This figure illustrates the simulated optimal trade policies under varying number of Chinese EV model entry (*x*-axis) across three scenarios: tariff with no revenue recycling (top left), tariff with revenue recycled as domestic subsidies (top right), and Quota policy (bottom left). The base year 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 E.11: Optimal Policy Mix and Welfare Contour with Top-5 or 20 Chinese EV models

(a) Top-5 Models

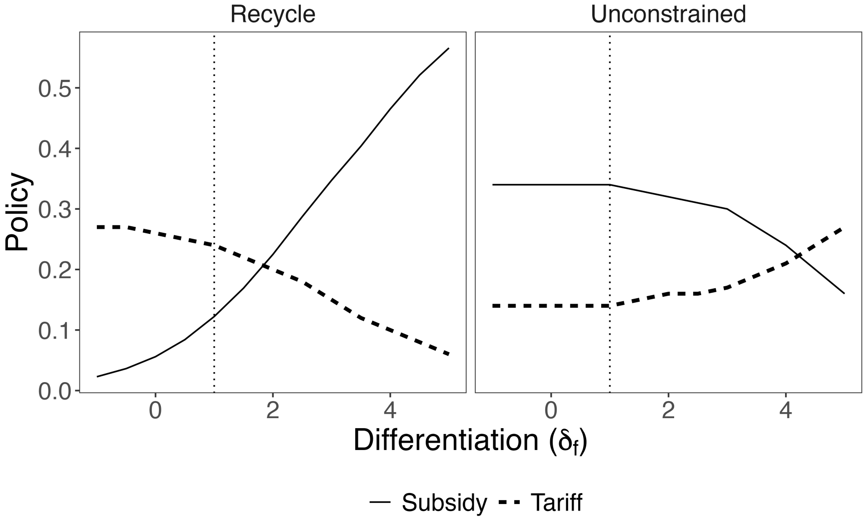


(b) Top-20 Models



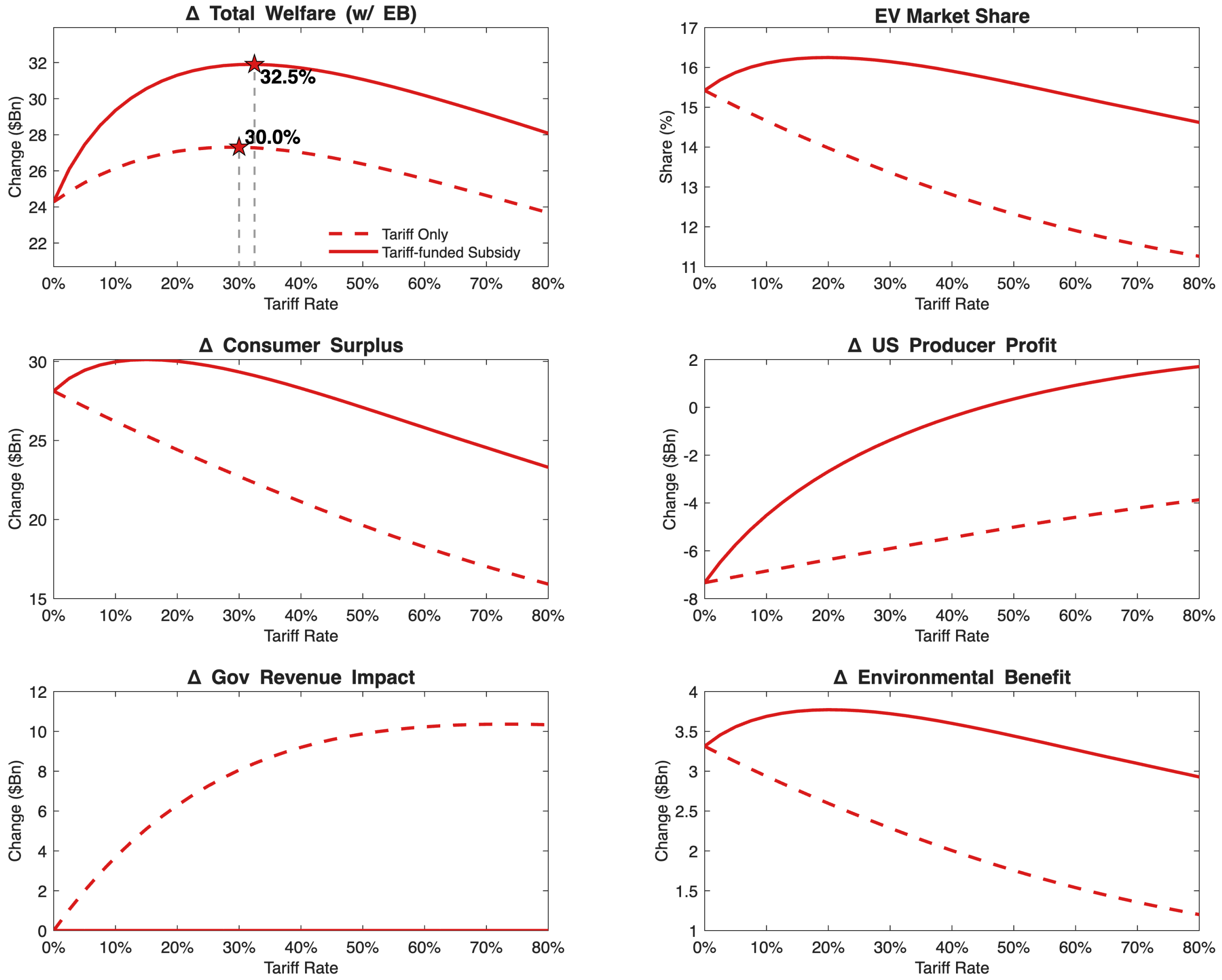
Notes: This figure replicates the analysis in Figure 2 using an identical setup, but introduces the top 5 or top 20 Chinese-manufactured EV models as entrants in Panels (a) and (b), respectively, instead of the top 10 models in the baseline. The horizontal axis represents the tariff rate on Chinese EVs, 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 unconstrained optimum 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.

Figure E.12: Optimal Policies by Product Differentiation



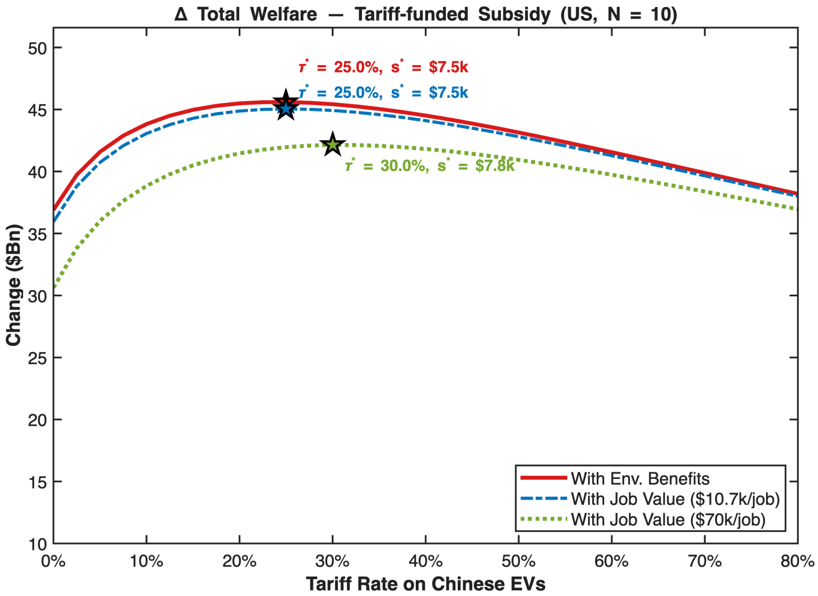
Notes: This figure shows optimal policies over the degree of product differentiation. The left panel is the unconstrained planner, and the right panel is the revenue recycling (balanced-budget) planner. The y-axis is the policy rate (tariff in dotted lines, subsidy in solid lines) and the x-axis is the 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 E.13: 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 E.14: Optimal Tariff-funded Subsidy Policy under Alternative Welfare Definitions, United States

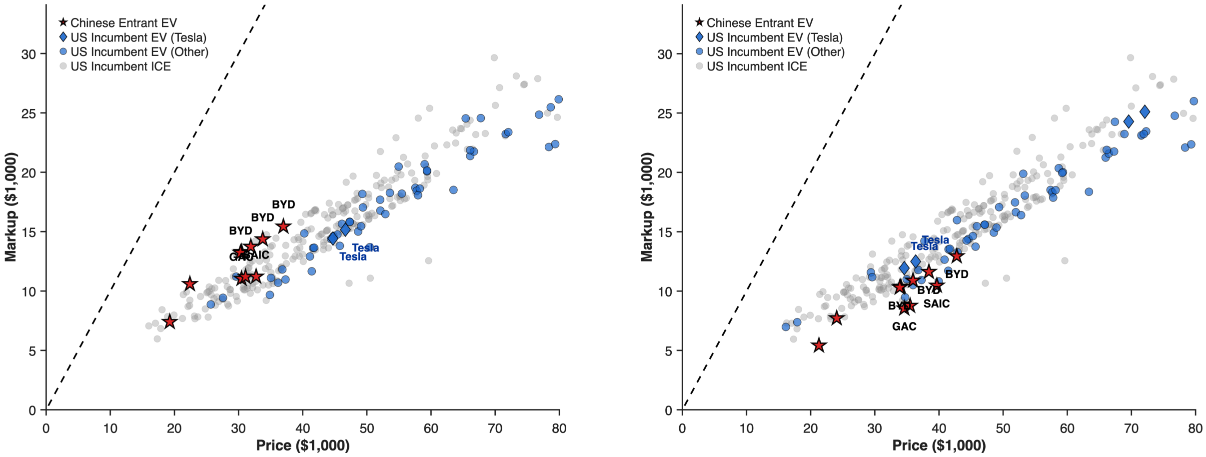


Notes: This figure plots the change in total welfare along the tariff-funded subsidy path for the United States, holding the number of Chinese EV entrants fixed at $N = 10$. Along this path, tariff revenue collected on Chinese EV imports is fully recycled as a per-unit subsidy to domestic EV buyers, so government revenue is balanced by construction. The horizontal axis shows the tariff rate on Chinese EVs; for each tariff level, the equilibrium subsidy is determined by the budget-clearing condition. The figure displays three welfare measures: welfare inclusive of environmental benefits only (red solid); welfare additionally incorporating a lower-bound estimate of the social value of manufacturing employment (blue dash-dot, valued at $10,700 per job-year following Slattery, 2025); and welfare incorporating an upper-bound estimate (green dotted, valued at the BLS NAICS 336 average auto manufacturing wage of $70,000 per job-year). Stars mark the optimal tariff rate and corresponding equilibrium subsidy for each welfare measure.

Figure E.15: Impacts of Policy on Pricing, Markup, Curvature, and Market Power

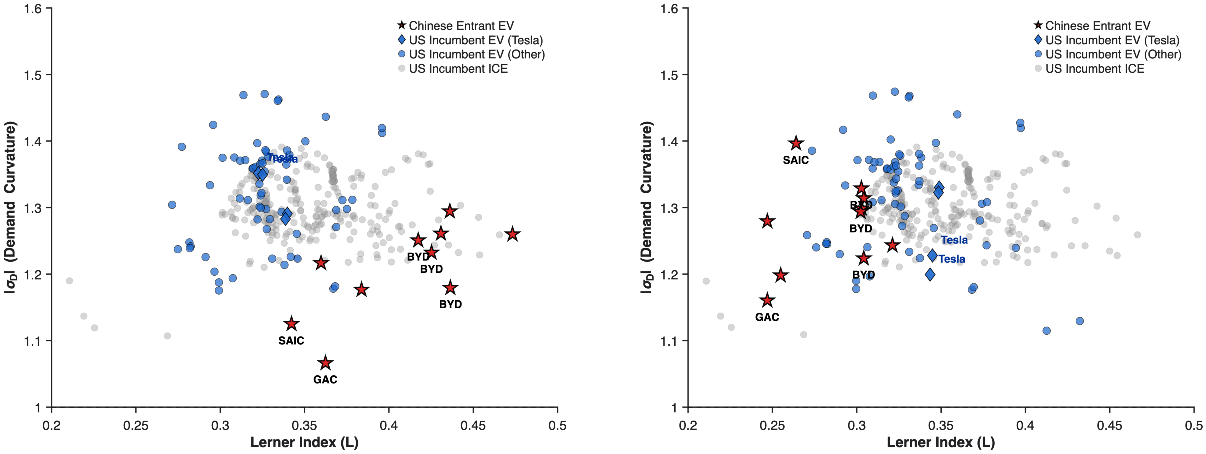
(a) Markup and Price:
No Policies

(b) Markup and Price:
Tariff-funded Subsidy



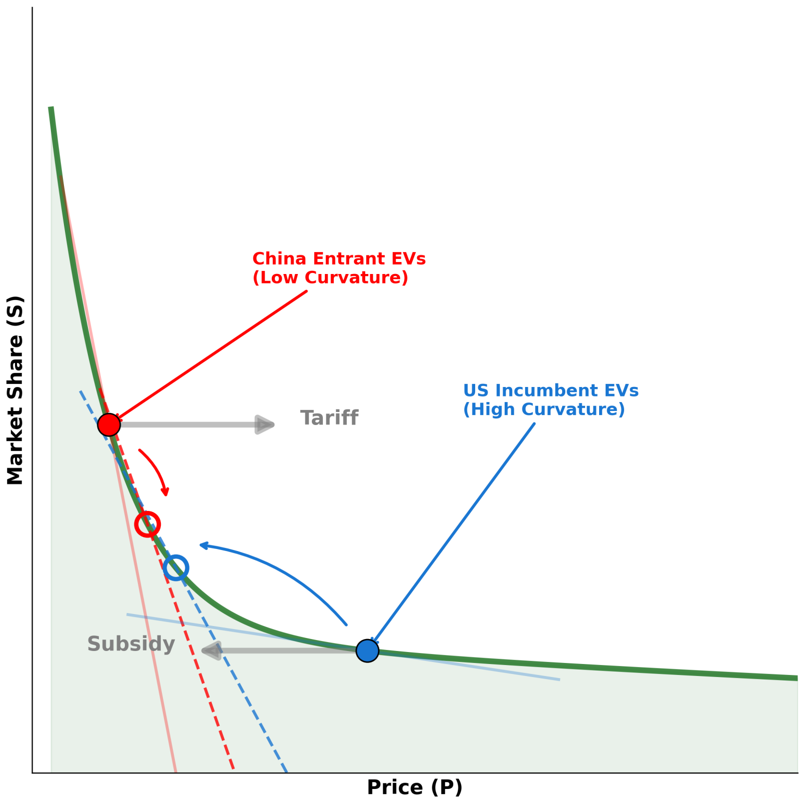
(c) Curvature and Market Power:
No Policies

(d) Curvature and Market Power:
Tariff-funded Subsidy



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.

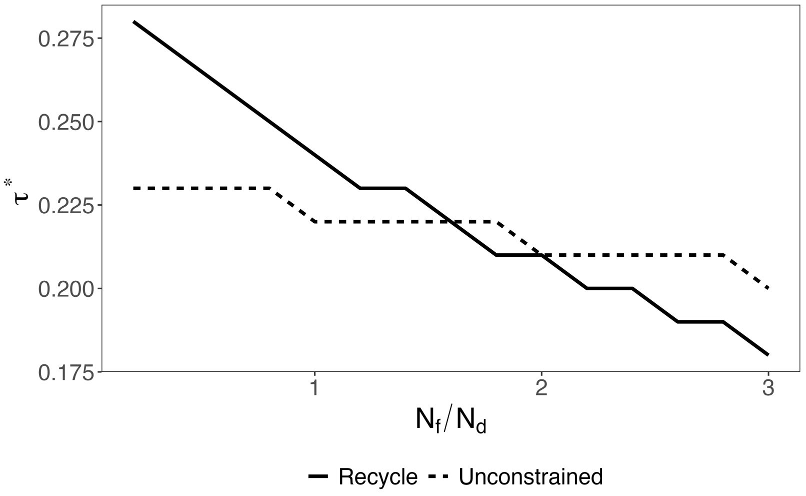
Figure E.16: Illustration the Tariff-recycling Subsidy: Chinese entrant EVs versus US incumbent EVs



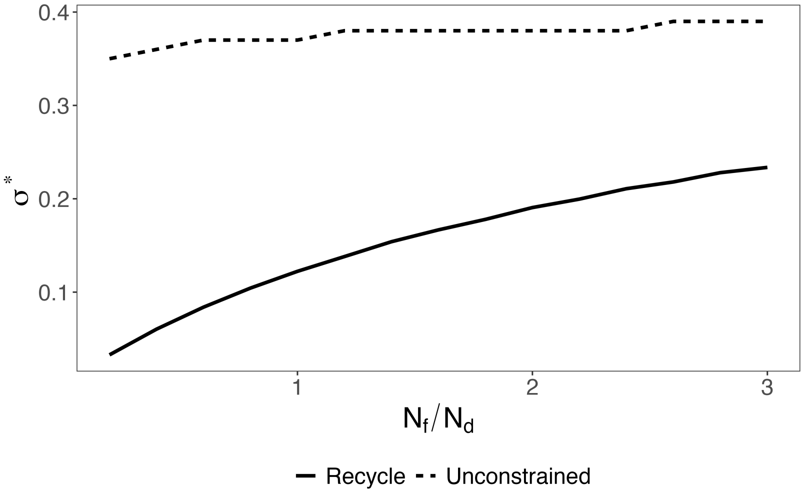
Notes: This figure illustrates the conceptual impacts of the tariff-recycling subsidy on the market equilibrium of Chinese entrant EVs and US incumbent EVs. The green solid curve represents the market demand. The solid red dot represents the initial equilibrium for China entrant EVs, and the solid blue 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 E.17: Optimal Policies by Market Structure

(a) Panel A. τ^* with $b = 0$

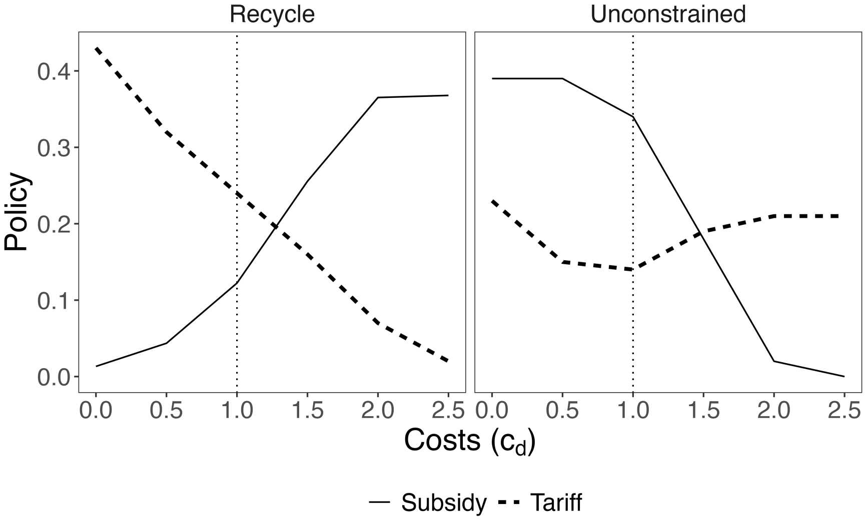


(b) Panel B. b^* with $\tau = 0$



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 E.18: 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.

F Appendix Tables

Table F.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 model sales 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 F.2: 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

Table F.3: Counterfactual: Add **Top 10** Chinese-manufactured EVs Sold in Europe 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 F.4: Optimal Policy Responses under Alternative Dynamic-Entry Scenarios: United States vs. Germany

	US Market			Germany Market		
Policy Scenario	Baseline	+1 model	+3 models	Baseline	+1 model	+3 models
Tariff Only						
Tariff Rate	26.5%	27.0%	27.0%	44.0%	44.5%	44.5%
Subsidy ($1,000)	0.00	0.00	0.00	0.00	0.00	0.00
ΔW^{EB} ($Bn)	41.10	43.78	46.56	23.16	24.97	25.95
Subsidy Only						
Tariff Rate	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Subsidy ($1,000)	9.60	9.80	10.10	12.00	12.00	12.00
ΔW^{EB} ($Bn)	43.26	46.45	49.75	22.81	24.87	26.00
Unconstrained Optimum						
Tariff Rate	21.5%	21.5%	21.5%	37.0%	35.5%	35.5%
Subsidy ($1,000)	8.50	8.70	9.00	10.60	9.70	9.70
ΔW^{EB} ($Bn)	45.72	48.89	52.17	25.95	27.71	28.77
Tariff-funded Subsidy						
Tariff Rate	24.0%	25.0%	26.0%	36.5%	36.0%	36.5%
Subsidy ($1,000)	7.38	7.20	7.05	10.87	9.64	9.36
ΔW^{EB} ($Bn)	45.60	48.65	51.78	25.95	27.71	28.77

Notes. This table reports the welfare-maximizing policy pair (tariff on Chinese EV imports and per-unit subsidy on domestic EV sales) in two markets under alternative dynamic-entry scenarios. In the *Baseline* columns no dynamically-introduced domestic model is added. In the *+1 model* and *+3 models* columns, one and three domestic models are dynamically added to the market, respectively. The number of Chinese entrants is held fixed at $N = 10$ throughout. The four row panels correspond to distinct policy scenarios. *Tariff Only* fixes the subsidy at zero; *Subsidy Only* fixes the tariff at zero; *Unconstrained Optimum* optimizes the two instruments jointly; *Tariff-funded Subsidy* restricts attention to the budget-balanced recycling path, along which tariff revenue collected on Chinese imports is rebated as a per-unit subsidy to domestic EVs. Within each panel, ΔW^{EB} denotes the change in total welfare inclusive of environmental benefits, measured in billions of U.S. dollars relative to the corresponding no-policy counterfactual. The underlying policy grid in the dynamic counterfactuals is finer than that used in the baseline static analysis: tariffs are searched in 0.5 percentage-point increments and subsidies in $100 increments.

Table F.5: Welfare under Alternative Per-Job Valuations and MCPF Multipliers: **Top 10** Chinese EV Entry, United States

	(1)	(2)	(3)	(4)
	Add top 10 China manufactured EV + Optimal designs			
	Tariff Only	*Subsidy Only*	*Both*	*Recycling*
Tariff / Subsidy	27.5% / $0.00k	0.0% / $9.60k	22.5% / $8.40k	25.0% / $7.47k
Δ *Welfare incl. monetized job value ($Bn):*				
Slattery (2025), $10.7k/job (LB)	40.20	42.20	44.89	44.78
Bartik (2015), $12.25k/job	40.11	42.09	44.81	44.70
Bartik (2015) × Moretti (2010), $31.85k/job	38.88	40.72	43.81	43.68
Annual wage, $70k/job (UB)	36.48	38.05	41.84	41.70
Allcott et al. (2026), $169k/job	30.26	31.12	36.74	36.55
Δ *Welfare incl. MCPF penalty ($Bn):*				
$\chi = 1.1$	40.88	41.47	45.14	45.33
$\chi = 1.3$	40.88	38.51	44.54	45.33
$\chi = 1.5$	40.88	35.56	43.94	45.33

Notes. This table reports the welfare effect of introducing the top 10 Chinese EV models in the US market under four optimal-policy regimes (*Tariff Only*, *Subsidy Only*, the joint unconstrained optimum *Both*, and budget-balanced *Recycling*), under two distinct robustness exercises. The upper panel varies the social value of a manufacturing job across five alternative per-job-year valuations. Each cell in this panel reports $\Delta\text{Welfare}^{\text{Job}}(w) = \Delta\text{Welfare}^{\text{EB}} + w \cdot \Delta\text{Jobs}$ in $Bn, where $\Delta\text{Welfare}^{\text{EB}}$ and ΔJobs are the welfare and manufacturing-employment changes reported in Table 4. The lower panel applies a marginal-cost-of-public-funds (MCPF) penalty that scales only the net fiscal deficit, leaving fiscal surpluses untouched (returned lump-sum at par). Each cell in this panel reports $\Delta\text{Welfare}^{\text{MCPF}}(\chi) = \Delta\text{Welfare}^{\text{EB}} - (\chi - 1) \cdot \max\{\text{Gov. Deficit}, 0\}$ in $Bn, where χ denotes the MCPF multiplier and three values $\chi \in \{1.1, 1.3, 1.5\}$ are reported, spanning a range consistent with the public-finance literature. See Appendix C.4 for the construction of ΔJobs and a description of each per-job-year benchmark, and Appendix C.5 for the MCPF panel. All monetary values are in 2023 US dollars and reported relative to the 2023 status-quo baseline.

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