Subsidies, Reallocation, and the Rise of China's Electric-Vehicle Market, 2015–2024

The University of Hong Kong

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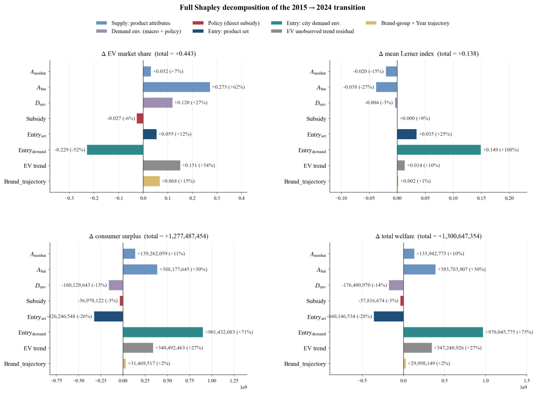
Section 1

The fastest technology transition on record

China's EV share rose from $< 1\%$ to 44% in a single decade — not a gradual S-curve, a near-vertical ascent in the second half.

Adoption & technology	
EV market share	$1.0\% \to 45.3\%$
EV nameplates	$52 \to 494$
Mean EV range (km)	$141 \to 352$
Battery ($/kWh)	$373 \to 115$
Demand side, in 10k ¥	
Urban income	$3.34 \to 5.76$
EV net price	$18.9 \to 17.8$
ICE net price	$15.1 \to 20.5$

The EV–ICE price premium *reversed*; urban income rose 73%.



Eight-block Shapley decomposition of the 2015⟶2024 change in EV share, mean Lerner, CS, and TW.

Heterogeneous diffusion — a bottom-up pattern

Adoption began among lower-income buyers, lower-tier cities, budget segments, then propagated upward.

Income / price segment

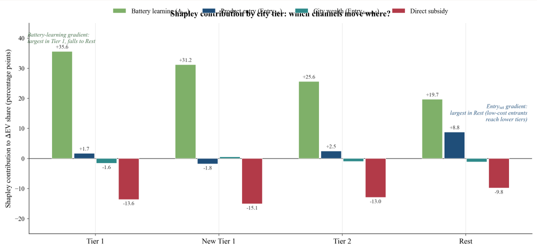
- Early (2015–18): lower-income / Budget (<¥150k)
- Late (2019–24): higher-income / Mid & Premium

City tier

- Early: Tier 2 and Rest cities
- Late: Tier 1 and New Tier 1

Dominant firms

- Early: Private National (BYD, Wuling, Chery)
- Late: New Forces (NIO, XPeng, Xiaomi) + BYD



Opposite of the typical luxury-first U.S. adoption story.

Three central questions

1. *Adoption margin.* What drove the $+44.3$ pp rise in EV market share? Product entry, demand environment, battery learning, or direct subsidies?
2. *Markup margin.* Did aggregate markups rise through within-firm growth, or through reallocation toward high-markup firms?
3. *Subsidy incidence.* Who benefited from the subsidy regime, statically and dynamically? What would the market look like if subsidies had never existed?

Methodological contributions

- Random-coefficient logit demand on a 79-market, 10-year panel (N=$496{,}591$)
- Shapley value over $2^8 = 256$ counterfactual equilibria — extends Grieco, Murry & Yurukoglu (2024) from 4 to 8 blocks
- Olley–Pakes decomposition of the Lerner index — first application in an automotive BLP setting
- Forward simulation with Wright's-Law battery-cost feedback, endogenous product exit, and an *empirically calibrated* dropout threshold

Section 2

Data — four sources, 79 markets, ten years

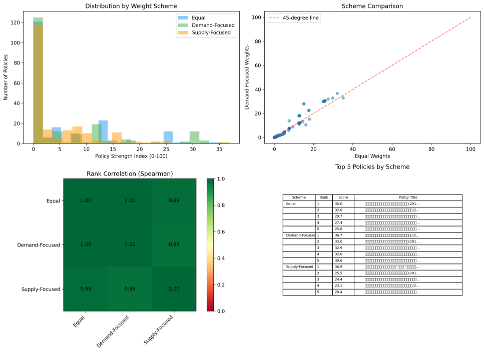
Four primary sources

- Proprietary registration panel (Model × City, 2014–2024)
- China City Statistical Yearbook 6.0 (income, urbanisation, education, population)
- PKULaw: hand-coded EV-policy corpus (4,122 documents)
- Subsidy schedules: central NEV + local + tax exemption

Sample design

- Fuel: BEV, PHEV, REEV (pooled as EV), HEV, ICEV
- Firm groups: BYD, Tesla, Trad-OEM, New Forces, Private National, Other
- Price tiers: Budget (<¥150k), Mid (¥150–300k), Premium (>¥300k)

Final panel: 79 markets (52 standalone cities + 27 province residuals), 496,591 product-market-year observations.



Demand model — random-coefficient logit BLP

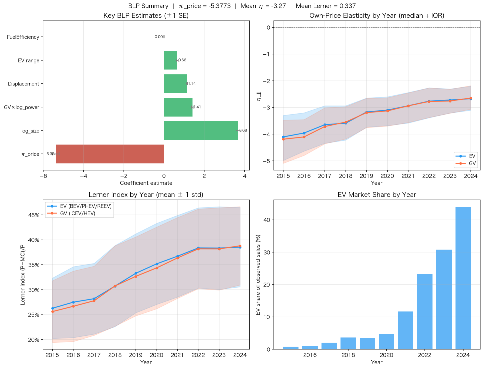
Income-heterogeneous price coefficient lets subsidies hit lower-income buyers harder.

$$u_{ijct} = \delta_{jct} + \alpha_{ic} \log p_{jct} + \varepsilon_{ijct}$$

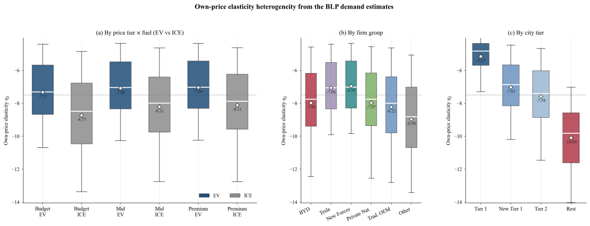
$$\alpha_{ic} = \hat{\pi}_p \cdot (y_{ic}/\bar{y})^{-1}$$

$$\delta_{jct} = X'_{jt}\beta_x + Z'_{ct}\beta_z + \xi_{jct}$$

- Income draws $y_{ic} \sim F_{y|c}$ (city-level log-normal)
- National pricing (single price across cities)
- GMM with BLP-style differentiation IVs + battery-cost shifters
- Supply: multi-product Bertrand–Nash $\rightarrow$ marginal cost from FOC



Demand estimates — own-price elasticity heterogeneity



City-tier gradient

Mean elasticity rises in magnitude from -3.64 in Tier 1 to -7.94 in the Rest tier — nearly double. Drives the Entry_demand block's outsize Lerner contribution.

Firm-group pattern

Tesla and New Forces sell into Tier-1 / New-Tier-1 (smallest $|\varepsilon|$); Other (exited lower-tier ICE brands) carries the largest $|\varepsilon|$.

Lerner indices by fuel

$L_{\text{REEV}}=0.41 \quad L_{\text{BEV}}=0.39 \quad L_{\text{PHEV}}=0.39 \quad L_{\text{ICE}}=0.33$

EVs systematically less price-elastic than ICE within every tier.

The eight-block decomposition framework

Block	Economic content
A_{nonbat}	Non-battery product attributes (size, power, body type)
A_{bat}	Battery & EV characteristics (range, BNEF battery cost)
D_{env}	Demand environment (oil, urbanisation, non-subsidy policy)
Subsidy	Direct purchase subsidy + tax exemption + trade-in voucher
Entry_set	Product-set composition (which products in choice set)
Entry_demand	Per-city demand environment (population, income distribution)
EV_trend	EV-specific unobserved trend (EV × Year FE + residual)
Brand_trajectory	Per-brand annual residual drift (Brand × Year cell-mean)

Shapley over $2^8 = 256$ counterfactual equilibria

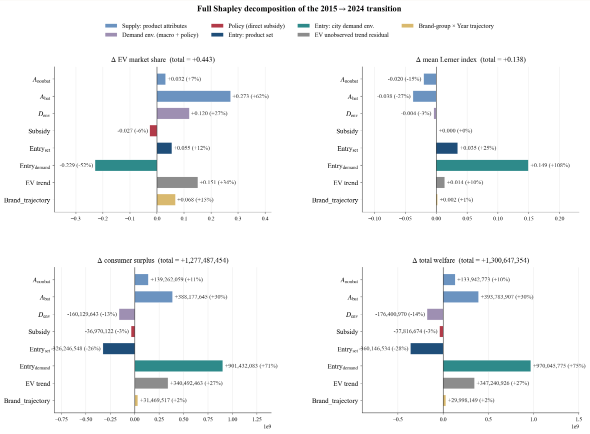
- Symmetric attribution (does not depend on activation order)
- Efficient: contributions sum exactly to the observed total change
- Each coalition solves the multi-market Bertrand–Nash equilibrium

Section 3

ΔEV share decomposition

Total EV share change: **+44.3 pp** (2015 → 2024)

Block	ΔEV (pp)	%
A_{bat}	+27.3	62
EV_trend	+15.1	34
D_{env}	+12.0	27
Brand_trajectory	+6.8	15
Entry_set	+5.5	12
A_{nonbat}	+3.2	7
Subsidy	−2.7	−6
Entry_demand	−22.9	−52



Battery learning + EV-specific trend dominate.

Direct subsidies −2.7 pp on the static margin. Entry_demand −22.9 pp via the wealth-effect channel.

Why does the static Subsidy block contribute only -2.7 pp?

Mechanism. The block toggles the subsidy schedule between its 2015 and 2024 levels. The schedule phased out over 2015–2022; activating the block in any coalition removes a positive 2015 wedge and yields a small negative effect.

Demographic triangle. The -2.7 pp aggregate hides sharp segment heterogeneity:

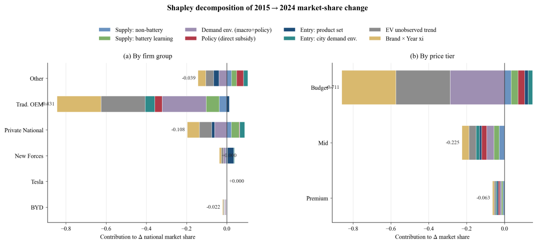
Segment	Subsidy ΔEV (pp)	% of own growth
Budget tier (<¥150k)	**−14.34**	−32.5%
Private National firms	**−17.78**	−48.6%
Rest-tier cities	−8.38	−20.4%

Caveat. Entry_set is treated as exogenous — any subsidy-induced entry is absorbed there. The static -2.7 pp is a *lower bound* on the regime's total 2024 contribution. The dynamic counterfactual (later) bounds it at -21.7 to -40.6 pp.

Subsidy heterogeneity — the demographic triangle

The subsidy was a transfer to lower-income buyers of budget-segment vehicles in lower-tier cities.

- Budget tier and Private National firms together carry the bulk of the subsidy attribution
- Rest-tier cities lose 20% of their own EV-share growth without the wedge
- Tier 1 (Beijing, Shanghai) is barely affected — they buy premium EVs that don't depend on the subsidy



Markup decomposition — within-firm channel dominates

Mean Lerner $0.178 \to 0.316$, $\Delta = +0.138$

Block	ΔLerner
Entry_demand	**+0.150**
Entry_set	$+0.035$
EV_trend	$+0.014$
Brand_trajectory	$+0.002$
Subsidy	~ 0
D_{env}	-0.004
A_{nonbat}	-0.021
A_{bat}	-0.038
Total	**+0.138**

Entry_demand carries 109% of ΔLerner.

Mechanism (3 channels)

1. Product-mix upgrading within incumbents (BYD's $\Delta\xi = +2.69$)
2. Brand-premium growth (Geely Lynk & Co, Chery OMODA, Wey)
3. Lower model-implied price elasticity from 73% income growth under $\alpha \propto y^{-1}$

Income growth $\to |\alpha_{ic}| \downarrow \to$ within-firm markups rise.

Direct subsidy contributes *essentially nothing* to markup growth.

Olley–Pakes — within-firm vs. reallocation

Aggregate markup growth driven *entirely* by within-firm growth, not by share reallocation.

Component	$\Delta\bar{L}$	%
Within-firm	+0.1035	+112%
Reallocation	−0.0111	−12%
Cross term	+0.0314	+34%
Sum	+0.1238	+134%
Observed $\Delta\bar{L}$	+0.0924	+100%
HHI 2015 → 2024	1,374 → 887 (−35.4%)	

Concentration fell as markups rose.

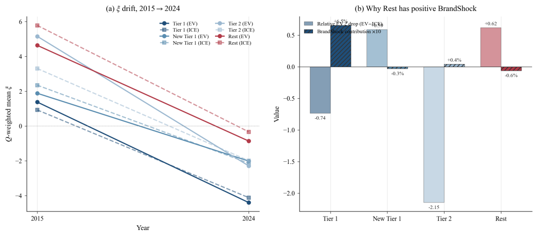
Opposite sign of the U.S. superstar-firm reallocation pattern (De Loecker, Eeckhout & Unger, 2020). Tesla and the New Forces gained share at *lower* Lerner; previously dominant incumbents lost share at *higher* Lerner.

Brand trajectories — winners and losers

Brand_trajectory contributes $+6.8$ pp to ΔEV share. Block constructed by post-hoc projection of the BLP residual onto (Brand $\times$ Year) cell means.

Dominant trajectories ($\Delta\xi$, 2015 $\rightarrow$ 2024):

- BYD: $+\mathbf{2.69}$ — budget BEV pioneer $\rightarrow$ mainstream NEV brand
- Chery: $+1.62$
- Beijing: $+1.48$
- Geely: $+1.38$
- Ford: -1.56 — foreign-incumbent retreat
- FAW: $-\mathbf{2.42}$ — SOE traditional decline



EV_trend block — anatomy of unobserved quality

EV_trend contributes $+15.1$ pp to ΔEV share (34%). It bundles three components.

Component	Content
(i) EV × Year FE	BLP-estimated time effects (negative, -2.9 in 2024)
(ii) (ev × Year) projection of ξ^{BLP}	Q-weighted EV-minus-ICE drift (positive, $+3.4$ units)
(iii) Within-cell rank residual	Pure within-(ev, Year) noise ($+11.8$ pp on diagnostic split)

Two sub-mechanisms in (iii):

- *New-Forces entrant under-fit*: Leapmotor's nine high-ξ nameplates (T03, C-series) carry $\sim$145k vehicles in 2024
- *Legacy-OEM EV gains*: FAW Bestune Pony, Chery QQ Ice Cream, Jiangling E200 outperform their ICE-dominated brand FE

Economic content: charging-network density, smart features, dealer-network buildout, consumer familiarity.

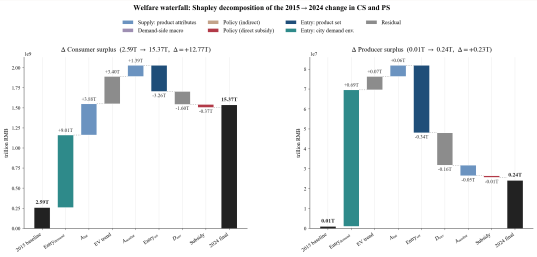
Welfare decomposition — consumer + total surplus

Aggregate

$\Delta CS = +12.77$ T RMB

$\Delta TW = +13.01$ T RMB

Block	ΔCS (T)	ΔTW (T)
Entry_demand	+9.01	+9.70
A_{bat}	+3.88	+3.94
EV_trend	+3.40	+3.47
A_{nonbat}	+1.39	+1.34
Brand_trajectory	+0.31	+0.30
Subsidy	−0.37	−0.38
D_{env}	−1.60	−1.76
Entry_set	−3.26	−3.60



The Entry_set paradox. Entry_set is the engine of EV adoption (+5.5 pp) but *reduces* CS by −3.26 T — the joint product-set swap removes cheap 2015 incumbents while introducing higher-priced 2024 entrants.

Section 4

Bounding the subsidy channel

Static Shapley fixes the product set; the never-existed-subsidy forward simulation re-introduces endogenous exit and Wright's-Law battery feedback.

Scen.	Rule	2024 CF (%)	ΔEV (pp)	Exits
A	Static Shapley Subsidy block (agent-integral wedge)	—	-2.7	0
B	Forward sim, $\theta = 0.25$ (lenient)	15.1	-26.6	461
C	Forward sim, $\theta = 0.50$ (relative-rule baseline)	6.5	-35.2	577
D	Forward sim, $\theta = 0.75$ (strict)	5.8	-36.0	619
E	**Empirical floor + grace period** (τ=0.021, calibrated from 711 observed exits)	**20.0**	**−21.7**	**355**
Memo:	full-BLP at $\theta = 0.5$ (agent-integral)	26.6	-40.6	537
Memo:	Wright's Law only, no exit	21.3	-23.9	—

Subsidies were constitutive of the bootstrap, not a marginal price wedge.

Dynamic range -21.7 to -40.6 pp *vs.* static -2.7 pp.

Static vs. dynamic incidence — two evaluations of one instrument

Static (Scenario A)

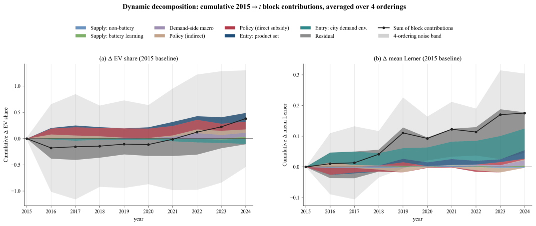
Phase-out at the 2024 margin.
→ −2.7 pp on EV share

Dynamic (Scenario E, preferred)

Never-existed-subsidy CF since 2015.
→ −21.7 pp on 2024 EV share

Gap. Phase 1 (2015–2019) bootstrap: subsidies funded cumulative production → Wright's-Law cost decline; charging-station density (network externalities); risk-capital flows underwriting NIO/XPeng/Leapmotor first-round VC; consumer learning.

Phase 2 (2020–2024): self-sustaining. The 2022 phase-out only *takes off the tail*.



Firm survival under the empirical rule (Scenario E)

Full-product-lifecycle profit retention by firm group × tier (% retained without the regime):

Firm group	Budget	Mid	Premium	All tiers
BYD	99.8	98.0	92.3	98.1
New Forces	95.8	99.9	100	99.8
Tesla	—	100	100	100
Trad. OEM	93.1	93.0	100	94.9
Private National	87.9	93.3	99.3	93.7
Other	59.0	84.3	100	73.3
BYD − NF gap (pp)	+4.0	−1.9	−7.7	−1.7

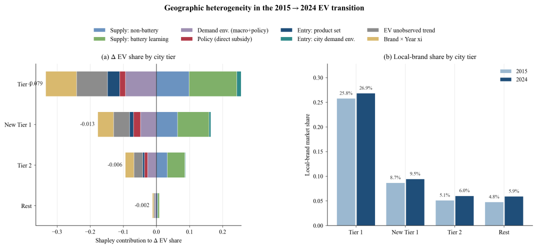
The asymmetry magnitude is rule-sensitive.

Under $\theta = 0.50$ (Scenario C, appendix), the BYD vs. NF gap is 13 pp (28 pp at corner cells) — a rule artefact: $\theta \cdot \pi^{\text{obs}}$ mechanically penalises high-observed-profit products. Under the empirical floor + 3-yr grace for post-2015 entrants, the gap collapses to -1.7 pp. **Robust:** BYD's competitive position predates the regime. **Rule-sensitive:** cross-firm magnitudes.

Geographic incidence — cities inherit through firm mix

Empirical rule (preferred): city dispersion 5.0 **pp**
Most-exposed: Henan-Other (5.2%), Shanxi-Other (4.8%), Liaoning-Other, Yunnan-Other.
Least-exposed: Shanghai (0.6%), Beijing (0.4%), Tibet, Qinghai.

Relative-threshold rule (appendix): dispersion 22.5 pp
Most-exposed: New-Forces-heavy coastal markets (Wenzhou, Shanghai, Taizhou).
Least-exposed: BYD-heavy Northern/Western (Harbin, Tibet, Urumqi).



Section 5

Generalizability — entry barriers × subsidy regime

	Active subsidy	No subsidy
Low entry barriers	**China EV decade.** Bootstrap completes; firm-origin asymmetry materialises (BYD vs. post-2015 New Forces).	Coordination failure (pre-FIT solar; pre-Tesla U.S. EV). Many fragmented entrants reach no minimum efficient scale. Phase 0.
High entry barriers	Rent capture by incumbents (German/Japanese EV transitions: VW, Toyota). No new-entrant cohort.	No transition.

Why the upper-left cell. NEV credit system advantaged new entrants over ICE incumbents; venture and municipal guidance-fund capital underwrote EV pure-plays at scale; battery vertical integration was open (CATL, BYD-battery, CALB sold to anyone).

Implication. The diagnostic toolkit (BLP-Shapley + OP + forward-sim firm-origin) transports to any cell. The substantive conclusion that subsidies are *constitutive* is specific to the upper-left.

Comparison with the literature

Grieco, Murry & Yurukoglu (2024) — 1980–2018 U.S. autos
Headline: prices rise, markups *fall*; supply-side cost decline + admin-fee growth absorb price.

Our setting reverses the sign of each piece:

- Markups rise ($+0.138$) while concentration falls (HHI $1374 \rightarrow 887$)
- Battery cost *collapses* (-69%); cost-pass-through dominates supply
- Demand-side wealth-effect channel from 73% income growth (muted in U.S.)

Hu, Yin & Zhao (2025) — BEV dynamic demand-supply
Operational (Phase 2): alternative subsidy schedules conditional on regime existing. Consumer temporal substitution as dynamic margin.

Our paper: constitutive (Phase 1⟶2 transition). Never-existed regime; firm-survival as dynamic margin. Operational-vs-constitutive complement.

Other strands. Olley–Pakes within-firm $\gg$ reallocation, the inverse of De Loecker, Eeckhout & Unger (2020) U.S. superstar pattern. Wright's-Law dynamics extend Springel (2021) from charging to combined battery learning + entry.

Three findings

1. **The static subsidy illusion.** Direct purchase subsidies contribute -2.7 pp to 2015–2024 EV share growth (statically), because the $2015 \to 2024$ phase-out removes a positive 2015 wedge. The contribution is concentrated in the budget–low-tier–Private-National demographic triangle.
2. **The engines of diffusion.** Battery learning (A_{bat}, $+27.3$ pp) and an EV-specific unobserved trend ($+15.1$ pp) drive most of the adoption rise; income growth raises markups within firms (112% within-firm in OP) but *lowers* model-implied EV adoption (-22.9 pp) through the wealth-effect channel.
3. **Dynamic learning + asymmetry.** Forward-sim CF gives -21.7 pp (empirical, identified) to -40.6 pp (full-BLP $\theta{=}0.5$): subsidies were constitutive of the bootstrap. BYD's competitive position predates the regime; the post-2015 New Forces emerged within it. The cross-firm asymmetry magnitude is rule-sensitive.

Policy implications

- **For China (post-subsidy).** Manage market consolidation. Avoid local protectionism that props up uncompetitive legacy firms. The 2022 phase-out is well-designed: it removes a small marginal wedge while the ecosystem is self-sustaining.
- **For emerging markets (India, Brazil, Indonesia, ASEAN).** Demand-side subsidies are insufficient on their own. Pair fiscal incentives with supply-side openness: low entry barriers in the budget segment, open battery vertical integration, NEV-credit-style new-entrant advantages.
- **For the technology-diffusion literature.** Models must incorporate endogenous product-set expansion. Variety and quality of available products can drive adoption as much as, or more than, pure price declines. Pair BLP-Shapley with Olley–Pakes when the within-firm vs. reallocation question is first-order.
- **Phase-outs are a feature, not a bug.** A pre-announced credible phase-out forces firms to transition from subsidy-dependence to genuine WTP, weeding out inefficient entrants.

Roadmap for future work

- **Companion paper**: dynamic-entry model with fixed-cost primitives and forward-looking investment. Identifies the static-to-dynamic propagation channel that the bottom-up IV ($F = 3.75$) cannot.
- **Petrin-style micro-moments**: identify $\alpha(y)$ non-parametrically when individual-level purchase data become available. The finite-mixture R8 ($\sim 5\%$ across-tercile spread) suggests a flatter true gradient than y^{-1}.
- **Charging-infrastructure channel**: companion dual-network paper provides a Bartik shift-share IV that this paper's data cannot deliver.
- **Methodological extensions**: quantile-positioning of entrant brand FE at year of entry; full Brand $\times$ FuelType disaggregation (78 dual-fuel brands) to shrink the EV_trend residual.

Thank you

Heterogeneous Diffusion of a New Technology

Questions & discussion welcome

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Industrial Organization & Econometrics

Section 6

Appendix — demand estimation details

Instruments. BLP-style differentiation IVs (sums of rivals' continuous characteristics by same and rival firms) + cost shifters (battery price × vehicle battery capacity).

Identification. Price coefficient identified by differential exposure to cost shocks and exogenous variation in choice set across markets and time. Income heterogeneity from market-level income distributions correlated with aggregate market shares.

Key parameter estimates.

- $\hat{\pi}_p = -5.38$ (cluster-robust SE 0.587, $t = -9.2$)
- Quantity-weighted average elasticity $\bar{\varepsilon} = -6.23$
- Tier gradient: Tier 1 $-3.64 \rightarrow$ Rest -7.94
- Log-range coefficient $+0.661$ (SE 0.048)
- BNEF battery-cost loading on $\log(mc)$: $+0.374$

Appendix — the dropout-rule menu

Forward-sim drops product *j* in year *t* if its CF profit falls below a threshold. Two rule families:

Relative-threshold (Scenarios B, C, D). $\pi_j^{\text{cf}} < \theta \cdot \pi_{jt}^{\text{obs}}$. $\theta \in \{0.25, 0.50, 0.75\}$ brackets the answer at -26.6 to -36.0 pp. Mechanically penalises high-observed-profit products $\longrightarrow$ inflates cross-firm asymmetry magnitudes.

Empirical absolute-floor + grace period (Scenario E, preferred).

- Drop if $\pi_j^{\text{cf}} < \tau \cdot \text{median}(\pi_{j',t}^{\text{obs}} \mid j' \text{ surviving}_{2023+})$
- $\tau = 0.021$ calibrated as median ratio (exit-year profit / median surviving profit) across 711 observed product exits in 2015–2022
- Grace period: products from post-2015-entrant brands exempt for first 3 years (calibrated to VC-startup loss tolerance)

Result. 355 cumulative dropouts; 752 product-year tests saved by grace period; -21.7 pp on 2024 EV share. Identified threshold + realised firm-lifecycle behaviour.

Appendix — robustness checks

Demand specification ladder (Appendix B of paper):

- R1 Homog-α: Entry_demand Lerner contribution collapses from $+0.106$ to $+0.001$ (99% reduction). Confirms the income-RC drives the wealth-effect channel.
- R2 52-city subsample: $\hat{\pi}_p = -6.55$ (vs. -7.28 baseline). Stable.
- R3 2-RC range: $\hat{\sigma}_{\text{log range}} = +1.73$ ($t = 3.2$); Entry_demand grows to $+0.198$.
- R4 Education proxy: $\hat{\pi} = -6.61$. Any socioeconomic gradient with similar dispersion identifies the same channel.
- R5 Subperiods: 2015–19 sharper ($\hat{\pi}_p = -8.34$); 2020–24 hits the π-bound.
- R6 Bartik income IV: $\hat{\pi} = -6.53$ (correlation 0.992 with observed income). Endogenous within-city income shocks are not first-order.
- R7 Log-linear α: $\hat{\pi} = -9.24$.
- R8 Finite-mixture (3 income terciles): across-tercile spread is $\sim 5\%$ vs. $\sim 100\%$ predicted by y^{-1}. Reads as upper bound.
- R9 Reduced-form IV by tier: non-monotonic; weak instruments.

Appendix — Wright's Law calibration

$\text{cost}_t^{\text{cf}} = \hat{A} \cdot (\text{CumProd}_{t-1}^{\text{cf}})^{-\hat{B}}$

Fitted on the BNEF-vs-cumulative-production panel ($N = 10$):

- $\hat{A} = 2{,}418$
- $\hat{B} = 0.222$ (SE 0.029, $t = 7.68$, $R^2 = 0.88$)
- Learning rate: 14.3% per doubling of cumulative production
- Conservative vs. Ziegler (2021)'s 20–24% for global lithium-ion (China-only scale variable, global cost variable).

Year-by-year path (Wright's-Law only, no exit, $\theta \to 0$ limit):

Year	Actual EV (%)	No-policy EV (%)	Battery gap ($/kWh)
2015	0.96	0.09	0
2019	4.12	1.21	110
2022	25.61	22.03	2
2024	45.27	21.32	3

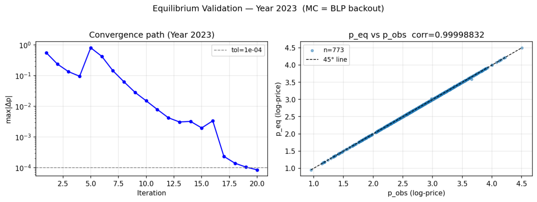
Total 2024 effect: $+23.9$ pp without endogenous exit.

Appendix — equilibrium validation

Solver. Anderson-accelerated fixed-point on the multi-market Bertrand–Nash FOC.

Anchor recovery. At the two anchor coalitions ($\emptyset$ and full), MC is backed out from FOC at observed prices; re-solving recovers prices to within 10^{-4} log units.

Convergence. Of the 256 coalitions, 254 reach strict tolerance; the 2 flagged by post-solve EV-share cap shift Shapley values by < 0.5 pp on every block.



Appendix — Olley–Pakes by firm group

Firm group	Within	Realloc	Cross	ω_{2015}	ω_{2024}
Traditional OEM	$+0.0605$	-0.0733	-0.0240	0.831	0.549
Independent Domestic	$+0.0134$	$+0.0206$	$+0.0095$	0.084	0.170
BYD	$+0.0068$	$+0.0278$	$+0.0106$	0.016	0.130
New Forces	$+0.0087$	$+0.0087$	$+0.0175$	0.000	0.053
Tesla	$+0.0046$	$+0.0046$	$+0.0091$	0.000	0.026
Other	$+0.0095$	$+0.0004$	$+0.0088$	0.068	0.073
Aggregate	$+0.1035$	-0.0111	$+0.0314$	1.000	1.000

Reading. Within-firm growth is broadly based — carried by every group. Negative aggregate reallocation is driven by Traditional OEM's -28.2 pp share loss at rising mean Lerner, partly offset by the entrant/expanding groups' $+0.062$ reallocation contribution.