Losing Market Dominance in a Growing Industry: BYD Company and Electric Vehicles in China

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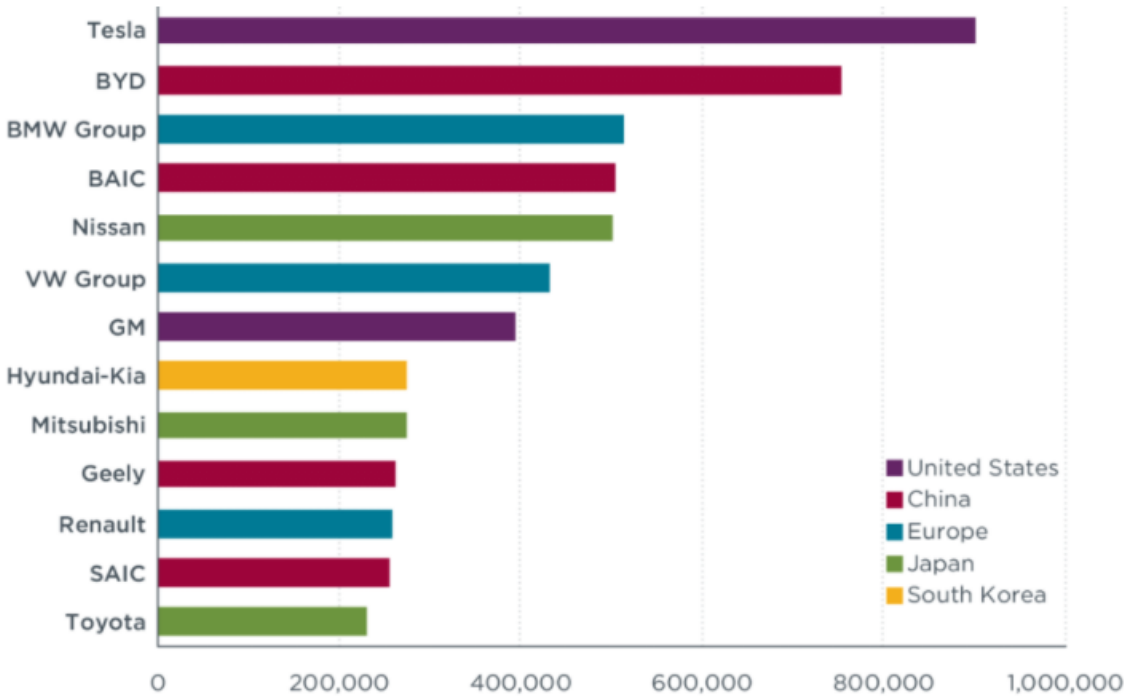
2022 DSE Conference, Australian National University

BYD Company

- One of China's largest car manufacturers & the world's leading EV producers

Figure: The global EV market: 2010-2019



Leading manufacturers in terms of cumulative global light-duty electric vehicle sales 2010-2019. Note: Based on EV-volumes (2020).

Figure Source: Jin. et al.(2021)

BYD to Tesla

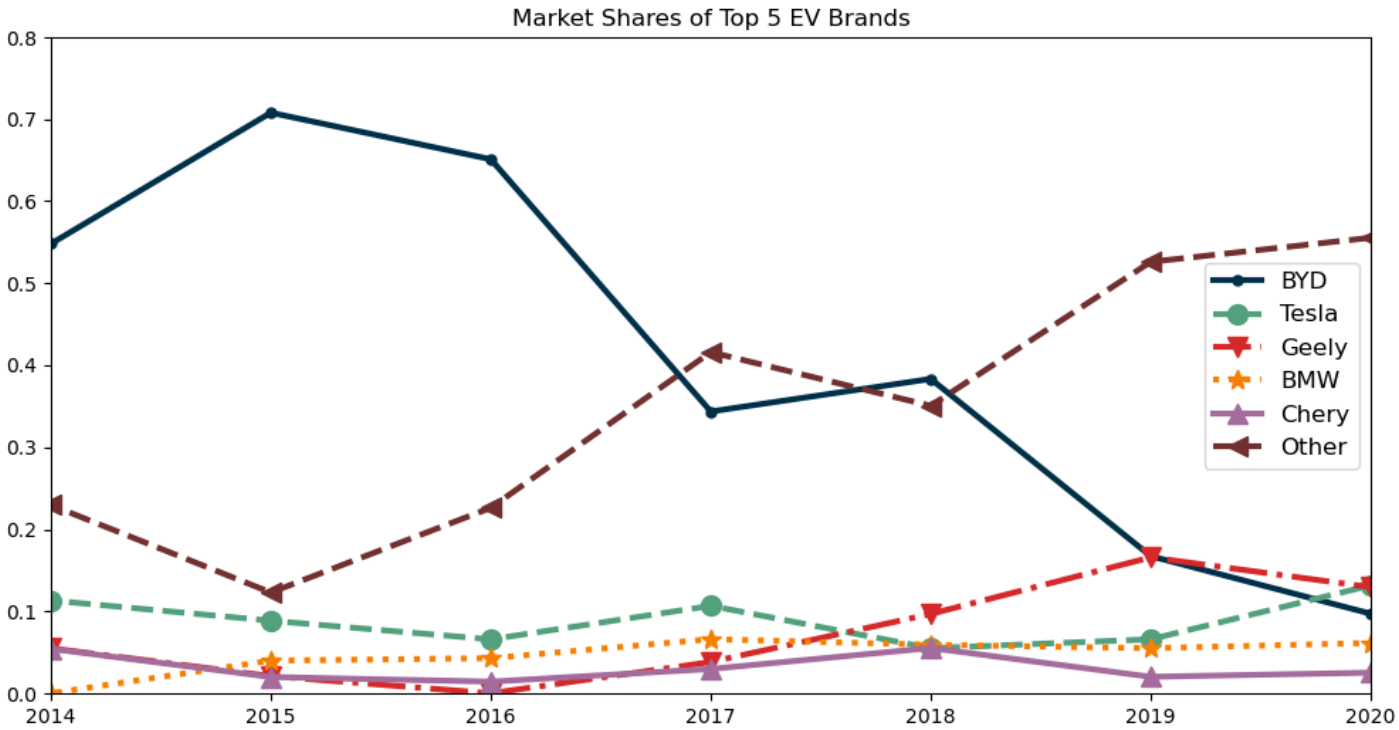
BYD's Market Position

- Production bases: Shenzhen, Beijing, **Xi'an**, Shanghai and Changsha
- Strength:
  - Technological superiority & cost advantage: developing, designing, and producing batteries on its own ▸ Global leading battery suppliers

Trends in Chinese EV market

1. National/ Local consumer EV mileage-based subsidy phasing out
   ▸ National and Local Subsidy
2. Entrant of the "new forces": XPeng, Li, NIO ▸ EV Characteristics Evolution
3. Incumbent firms introduce EV brands.
4. The "Drivabilities" and prices of EVs and ICEVs are getting closer.
   ▸ ICEV and EV Characteristics Evolution

BYD's decline in market shares



▶ National Shares

Research Question

- What are the contributions of each factor to explain the evolution of market shares and prices of
  - changes in competitions among incumbents firms
  - entries of new firms
  - marginal cost, demand shocks
  - subsidy
  - consumer type
- How do the incumbent firms respond to the changes in competition?

Data

- The Department of Motor Vehicles in the Xi'an city (Jan.2010-Aug.2020)
  - New car registration data at consumer transaction-level
    - VIN, purchase date, model name
    - buyer's age, gender, car ownership
- The largest China automobile website Autohome
  - Model attributes
    - seats, engine horsepower, suggested market price, displacement, etc.
    - EV driving range, EV horsepower.

Overview

- Estimate demand model
  - fixed-effect approach, accounting for household heterogeneity
- Estimate multi-product firms' marginal costs
  - assuming firms' competition mode
  - multi-product firm
  - no collusion
- Counterfactual decomposition
  - keeping all exogenous variables constant
  - allowing one exogeneous variable to evolve at a time
  - comparing the difference in market prices/price evolution paths

Contribution

- Explain how BYD lose its dominant position in a growing market.
- Counterfactual decomposition: decompose the algorithm that explains the contribution of each factor.
- Equilibrium solving: develop an algorithm to search for equilibrium for price competition with heterogeneous demand. Extend Garrido (2020).

Decomposition Algorithm[1]

- Let $\mathbf{Z}_t$ be the set of exogenous variables affecting equilibrium prices $\mathbf{p}_t$ and market shares $\mathbf{s}_t$ at t

$$\mathbf{Z}_t \equiv \{ \mathbf{x}_t, \mathbf{subsidy}_t, \boldsymbol{\xi}_t, \boldsymbol{\omega}_t, \mathbf{w}_t, \mathcal{J}_t : t = 1, 2, ..., T \}$$

where

  - $\mathcal{J}_t$ product set available.
  - $\mathbf{x}_t$ product characteristics.
  - $\boldsymbol{\xi}_t$ consumer preferences. ▸ Estimated Demand Shocks
  - $\boldsymbol{\omega}_t$ marginal cost shocks. ▸ Estimated Supply Shocks
  - $\mathbf{w}_t$ consumer weights.
  - $\mathbf{subsidy}_t$ subsidies.

Decomposition Algorithm[2]

Let $\mathcal{Z}$ represent the sequence of vectors$\{\mathbf{Z}_1, \mathbf{Z}_2, ..., \mathbf{Z}_T\}$ over the sample period
Define a *counterfactual decomposition* as a sequence of N cumulative changes in $\mathcal{Z}$ that are taken together imply a transformation from $\mathcal{Z}^{base}$ into $\mathcal{Z}^{factual}$:

- Explaining the evolution of market shares and prices:
- $\mathcal{Z}^{base} = \{\ \mathbf{Z}_t = \mathbf{Z}_1$: for any t=1, 2, ..., T $\}$

$$\mathcal{Z}^{factual} = \mathcal{Z}^{base} + \Delta\mathcal{Z}^1 + \Delta\mathcal{Z}^2 + ... + \Delta\mathcal{Z}^N$$

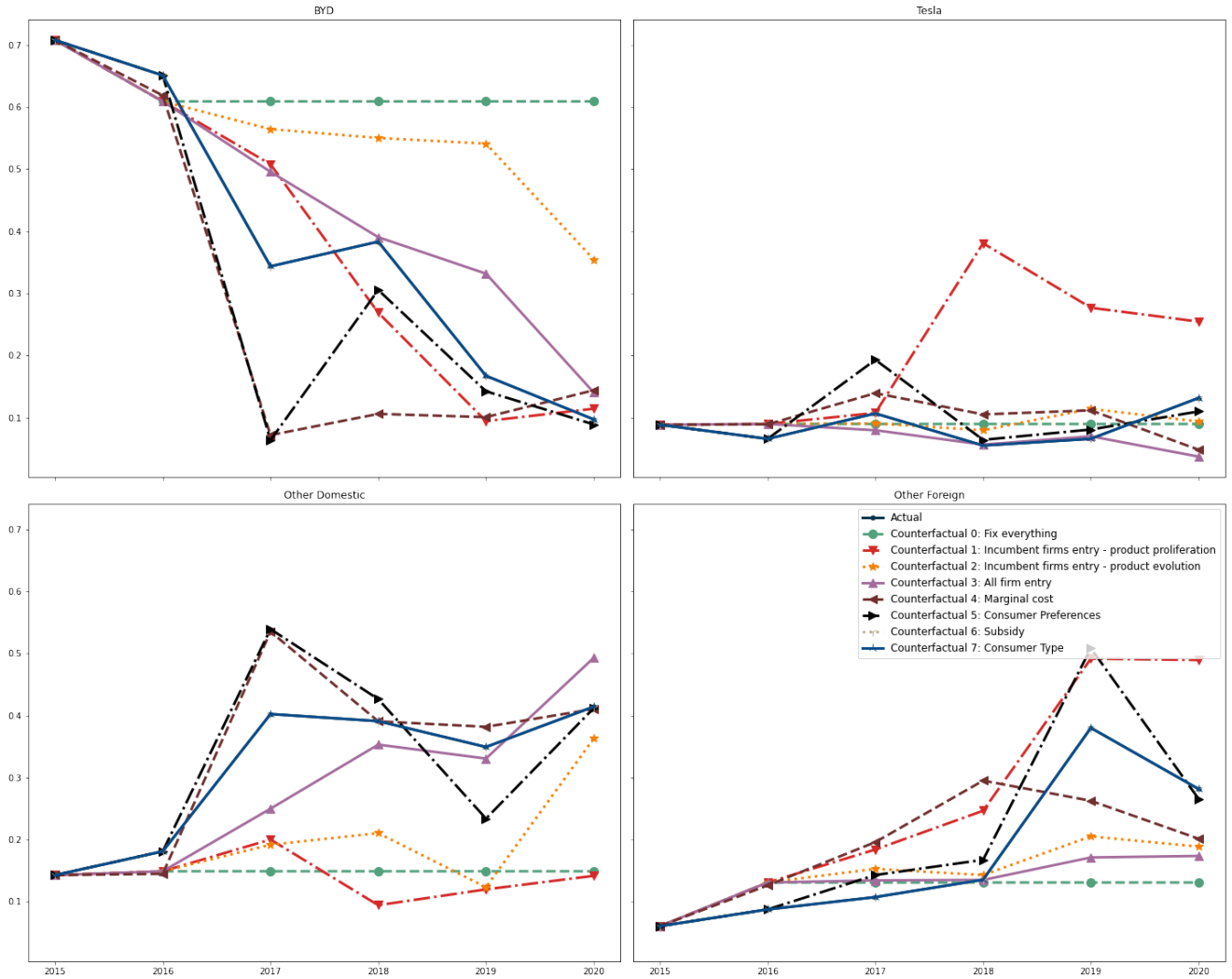
where $\Delta\mathcal{Z}^1, \Delta\mathcal{Z}^2, ..., \Delta\mathcal{Z}^N$ are this sequence of changes.

Estimated Parameters

Demand Parameters				*Marginal Cost Parameters*		
(Across Groups)	Mean	Max	Min		Estimates	S.E.
log(price - subsidy)	−1.5556	−2.6237	−0.3812	Intercept	−2.2543	(0.4542)
$\mathbb{1}_{EV}$	−0.62178	−1.14666	−0.129	$\mathbb{1}_{EV}$	8.4709	(0.4689)
Max Power	0.0028	$7.72 * 10^{-05}$	0.0068	Max Power	0.0844	(0.004)
Max Torque	0.0008	0.0002	0.0015	Max Torque	0.0066	(0.0014)
Displacement	−0.0400	−0.2693	0.1337	Displacement	3.3670	(0.2711)
Fuel Efficiency	0.1060	0.0236	0.1586	Fuel Efficiency	−0.1410	(0.0319)
EV Driving Range	$-6.20 * 10^{-05}$	−0.0027	0.0010	EV Driving Range	−0.0041	(0.002)

Decomposition Order

- Fixing the date to *January*, 2016, we identify the separate contributions of:
  - CF-1: changes in the proliferation of products by initial incumbent firms
  - CF-2: changes in product characteristics by incumbent firms
  - CF-3: the entry of new firms and their corresponding new products
  - CF-4: changes in marginal costs
  - CF-5: changes in consumer preferences
  - CF-6: changes in government subsidy policy
  - CF-7: changes in the distribution of consumer types


BYD
Tesla
Other Domestic
Other Foreign
Actual
Counterfactual 0: Fix everything
Counterfactual 1: Incumbent firms entry - product proliferation
Counterfactual 2: Incumbent firms entry - product evolution
Counterfactual 3: All firm entry
Counterfactual 4: Marginal cost
Counterfactual 5: Consumer Preferences
Counterfactual 6: Subsidy
Counterfactual 7: Consumer Type
0.1
0.2
0.3
0.4
0.5
0.6
0.7
2015
2016
2017
2018
2019
2020

Effect - Market Share Drop

	Incumbent Proliferation	Incumbent Quality	Entry	Cost Shocks		Consumer Preference	Subsidy	Consumer Type
				2020				
Market Share	Down	Up	Down	Down	Up	Mixed	Up	Up
Price	Up	Down	Up	Up	Down	Mixed	Down	Down

Effect - Quality Adjustment

	Incumbent Proliferation	Incumbent Quality	Entry	Cost Shocks		Consumer Preference	Subsidy	Consumer Type
				2020				
Market Share	Down	Up	Down	Down	Up	Mixed	Up	Up
Price	Up	Down	Up	Up	Down	Mixed	Down	Down

Conclusion

- New entrant and incumbent product proliferation serve have a **market stealing** effect BYD: lower market shares and lower prices.
- Incumbent quality evolution has a **cost reducing** effect BYD: higher market shares and lower prices.
- Yes, BYD is adapting its strategies in response to the new entrant.

What's next?

- Endogenous product quality choice in response to the policy.
- Vertical integration and potential foreclosure.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Leading Battery Supplies

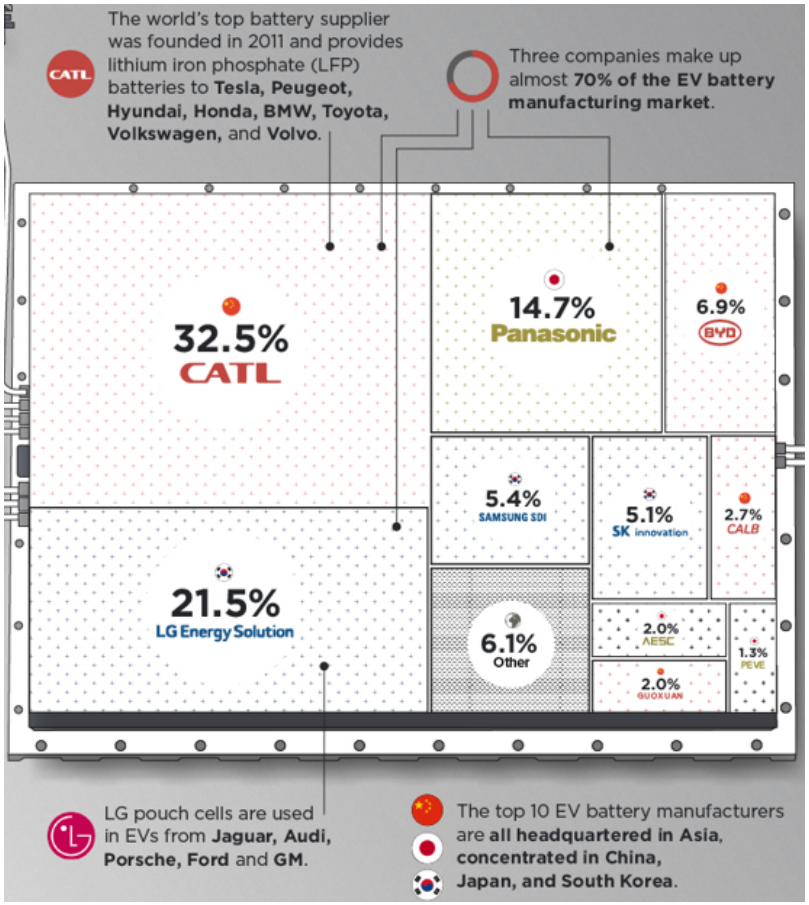

Figure Source: elements.visualcapitalist.com

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National Market Shares

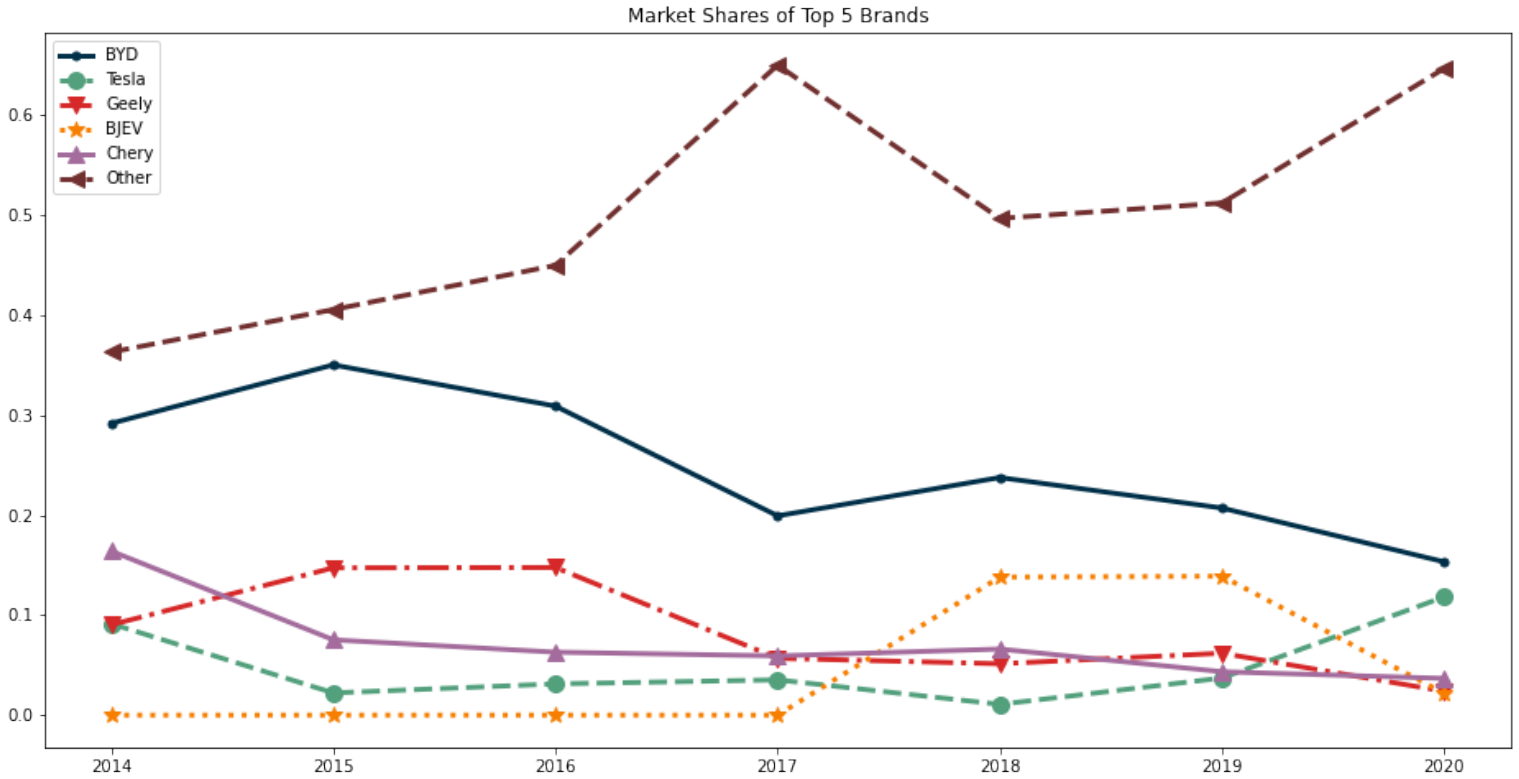


Figure: National Market Shares

▸ Decline Market Shares

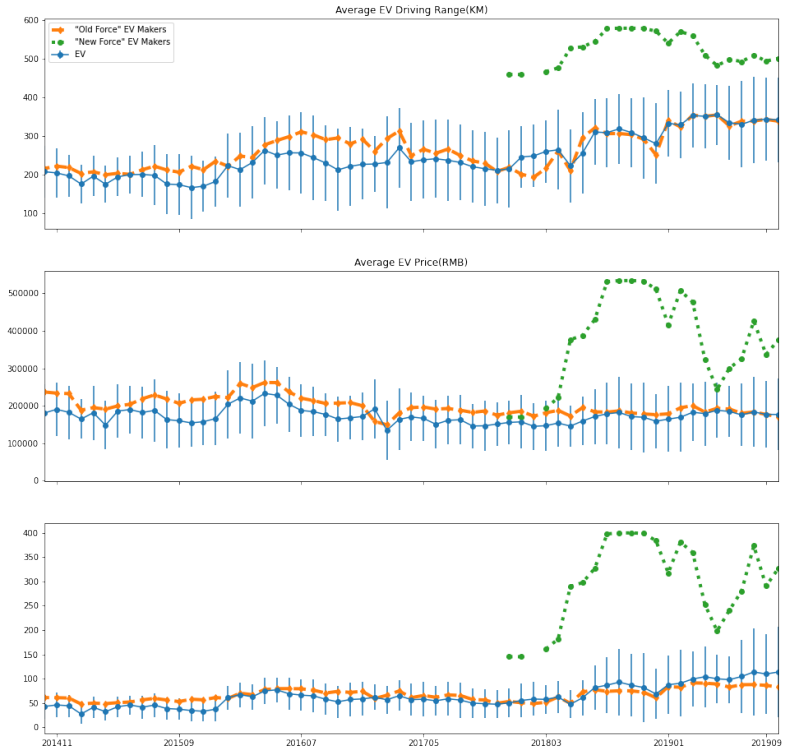
National and Local EV Subsidy: Phasing Out

Table: Subsidy amounts: National Subsidy and city Xi'an Supplement

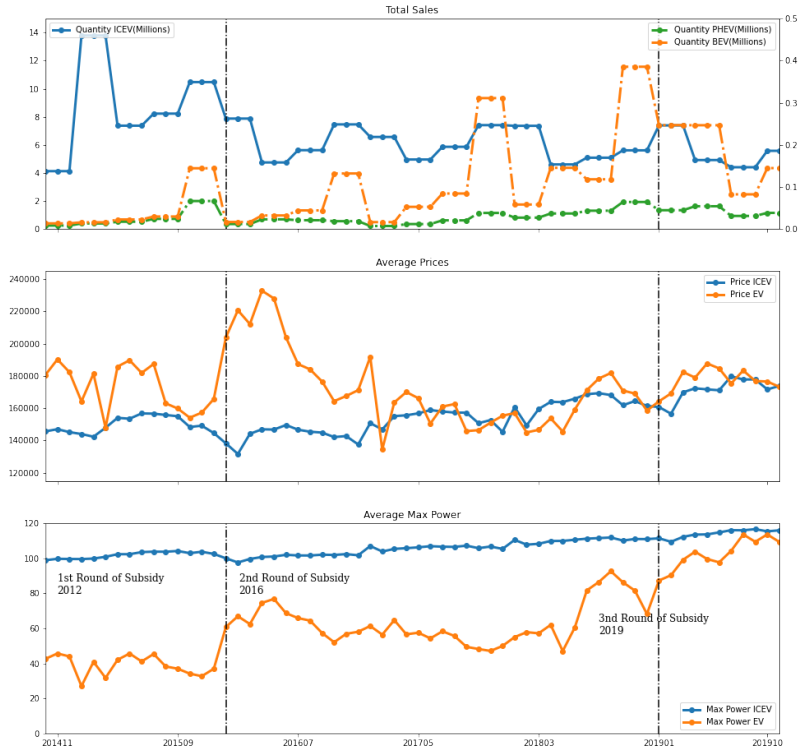
Time	National Subsidy by Driving Range (Unit:RMB 10,000)						Ratio Nat./city Xi'an
			BEV			PHEV	
	80-150	150-250	250-300	300-400	400+	50+	
2013	3.5	5.0	6.0	6.0	6.0	3.5	1:1
2014	3.325	4.75	5.7	5.7	5.7	3.325	1:1
2015	3.15	4.5	5.4	5.4	5.4	3.15	1:1
2016	2.5	4.5	5.5	5.5	5.5	3.0	1:1
2017	2.0	3.6	4.4	4.4	4.4	2.4	1:0.3
2018-2019(3)	1.5	2.4	3.4	4.5	5.0	2.2	1:0.3
2019(4)-2019(6)	0.9	1.44	2.04	2.7	3.0	1.3	1:0.3
2019(7)-2020(4)	-	-	-	1.8	2.5	1.0	none
2020(5)-2020(7)	-	-	-	1.62	2.25	0.85	none
2021	-	-	-	1.3	1.8	0.68	none

Note: The average RMB-to-USD exchange rate in 2021 was 0.1548.

EV Characteristics Evolution



EV and ICEV evolution



Summary statistics

Sample Period: Jan. 2010-Aug.2020					
Variable	Obs	Mean	Std. Dev.	Min	Max
Panel 1: Individual characteristics					
Age	2,872,002	34.90	9.40	10	89
Male dummy	2,872,002	0.72	0.45	0	1
OwnCarBefore	2,872,002	0.06	0.24	0	1
Panel 2: Product attributes: Gasoline, Diesel, and HEV models					
Retail price (10,000 RMB)	6,270	24.92	23.23	2.08	138
Maximum power (kw)	6,270	122.55	46.82	26.5	415
Engine displacement (liters)	6,270	1.94	0.60	0.8	6.5
Fuel capacity (liters)	6,270	55.86	19.26	28	138
Panel 3: Product attributes: BEV and PHEV models					
Retail price (10,000 RMB)	172	32.76	29.12	4.98	147.95
Subsidy (10,000 RMB)	172	3.71	2.84	0	11
Maximum power (kw)	172	139.25	117.8	9	568
PHEV Engine displacement (liters)	62	1.66	0.43	0.65	3
PHEV Fuel capacity (liters)	62	47.44	15.42	8	91.1
Driving range (km)	172	243.81	165.58	27	664

Warren Buffett's BYD Vs. Elon Musk's Tesla

- In 2008, Warren Buffett invested $232 million for a nearly 10% stake in BYD Back to BYD intro
- "Tesla is the world's largest electric vehicle maker, delivering 308,600 electric vehicles in the fourth quarter, up from 241,300 in Q3, 201,250 in Q2 and 184,800 in Q1. But BYD is catching up. BYD sold 93,945 new energy vehicles in December, up 218% vs. a year earlier," reports Ed Carson at *Investor's Business Daily*
- Differences: "Tesla, targeting the luxury and affordable luxury markets, has far-higher selling prices than BYD," notes Carson. But, BYD's lower-cost EVs and hybrids are selling for between $15,000–$34,000. That said, BYD is now trying to offer higher-priced EVs like the Han, which tops out at about $40,000.
- Both companies make their own chips and energy storage products. But BYD also has a strong business selling electric buses and EV batteries. In fact, according to Carson, "There has been repeated but unconfirmed speculation that Tesla Shanghai will use BYD batteries starting in 2022."

Estimation: zero-market-shares problem

- The Chinese EV market is an emerging market
  - a large number of new products entering
  - a small even zero market shares for some combinations of consumer groups and quarters
- Methods for market level data cannot incorporate this issue
  - selection biases by ignoring
- Apply Gandhi et al. (2019)'s method
  - assumes zero market shares come from a relatively small population of consumers that implies a strictly positive probability for the event $s_{jt}^h = 0$
  - deriving lower and upper bounds for the true consumer choice probabilities
  - a *Laplace correction factor* forcing the corrected market share to fall into $(0, 1)$

$$\tilde{s}_{jt}^h = \begin{cases} s_{0t}^h \times (1 - \kappa) & \text{for } j = 0 \\ s_{jt}^h + \kappa \times s_{0t}^h / J_t & \text{for } j \neq 0 \end{cases}$$

  - ★ s_{0t}^h: market share of the outside good, $\kappa \in (0, 1)$: small constant
  - ★ $\kappa = 0.001$ in the paper back

Estimation: IV

Endogeneity: $\log(p_{jt} - sub_{jt})$

- Solution: BLP-type IV

$$z_{rjt}(\rho) = \sum_{k \in \mathcal{J}_t} \mathbf{1}\{k \notin \mathcal{J}_{b(j)} \ \& \ |x_{rkt} - x_{rjt}| \leq \rho\}$$

- $z_{rjt}(\rho)$: the number of competing car models with a value of attribute r within a neighborhood-ρ of that attribute for product j
- ρ=0.5, 0.7, 1.0, 1.5

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Estimation: Gauss-Newton Approximation

Extending the work by Garrido (2020)

- For outer loop iteration $k = 1, 2, \ldots$
  - Compute the inclusive function $\mathbf{I}^h(\mathbf{p}) = \log\left(\sum_{j \in \mathcal{J}} \exp(\bar{u}^h_{jt}(p_j))\right)$ for $h \in \mathcal{H}$
  - For inner-loop iteration $l = 1, 2, \ldots, N$
    - Compute the demand function given the inclusive function and the prices from last iteration $s_j^{h(l)} = \mathrm{D}_j^h(p_j^{(k-1)}, \mathbf{I}^{h,(k)}) = \exp(\bar{u}^h_{jt}(p_j)) / \exp(\mathbf{I}^h(\mathbf{p}))$
    - Compute the gradient $\mathrm{G}_j(p_j^{(l-1)}, s_j^{(l)}) = \frac{d\Pi_{f(j),t}(\mathbf{p}_t)}{dp_j}$, $\Pi_{f(j),t}(\mathbf{p}_t)$ is the profit for firm f, producer of j.
    - Compute the diagonal element of the Hessian matrix for the price $\mathrm{H}_j(p_j^{(l-1)}, s_j^{(l)}) = \frac{d^2\Pi_{f(j),t}(\mathbf{p}_t)}{dp_j^2}$.
    - Update the price vector $\mathrm{p}_j^{(l)} = \mathrm{p}_j^{(l-1)} - \mathrm{G}_j(p_j^{(k-1)}, s_j^{(l)}) / \mathrm{H}_j(p_j^{(k-1)}, s_j^{(l)})$

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Demand Shocks

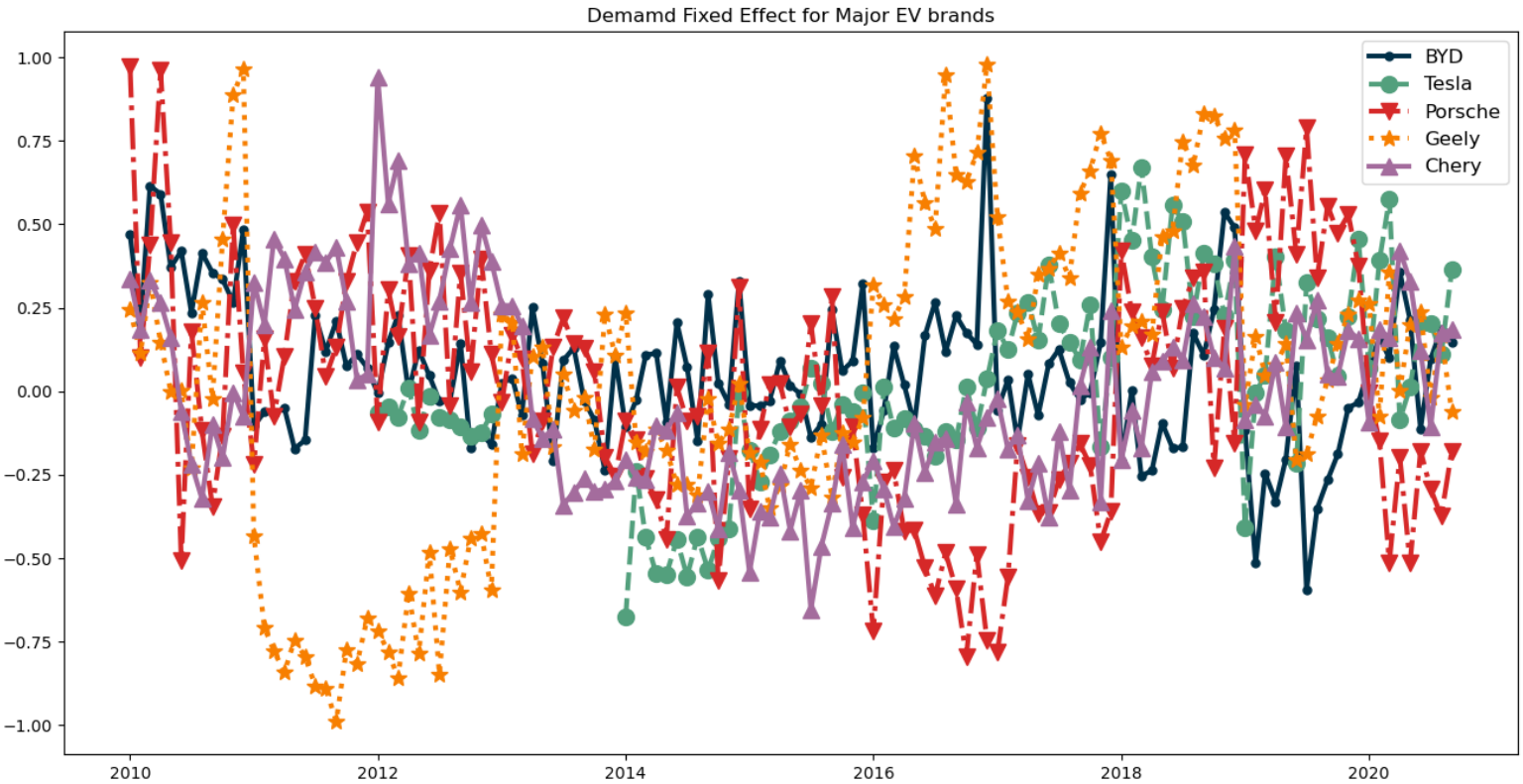

Figure: Estimated Average Demand Shocks

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Supply Shocks

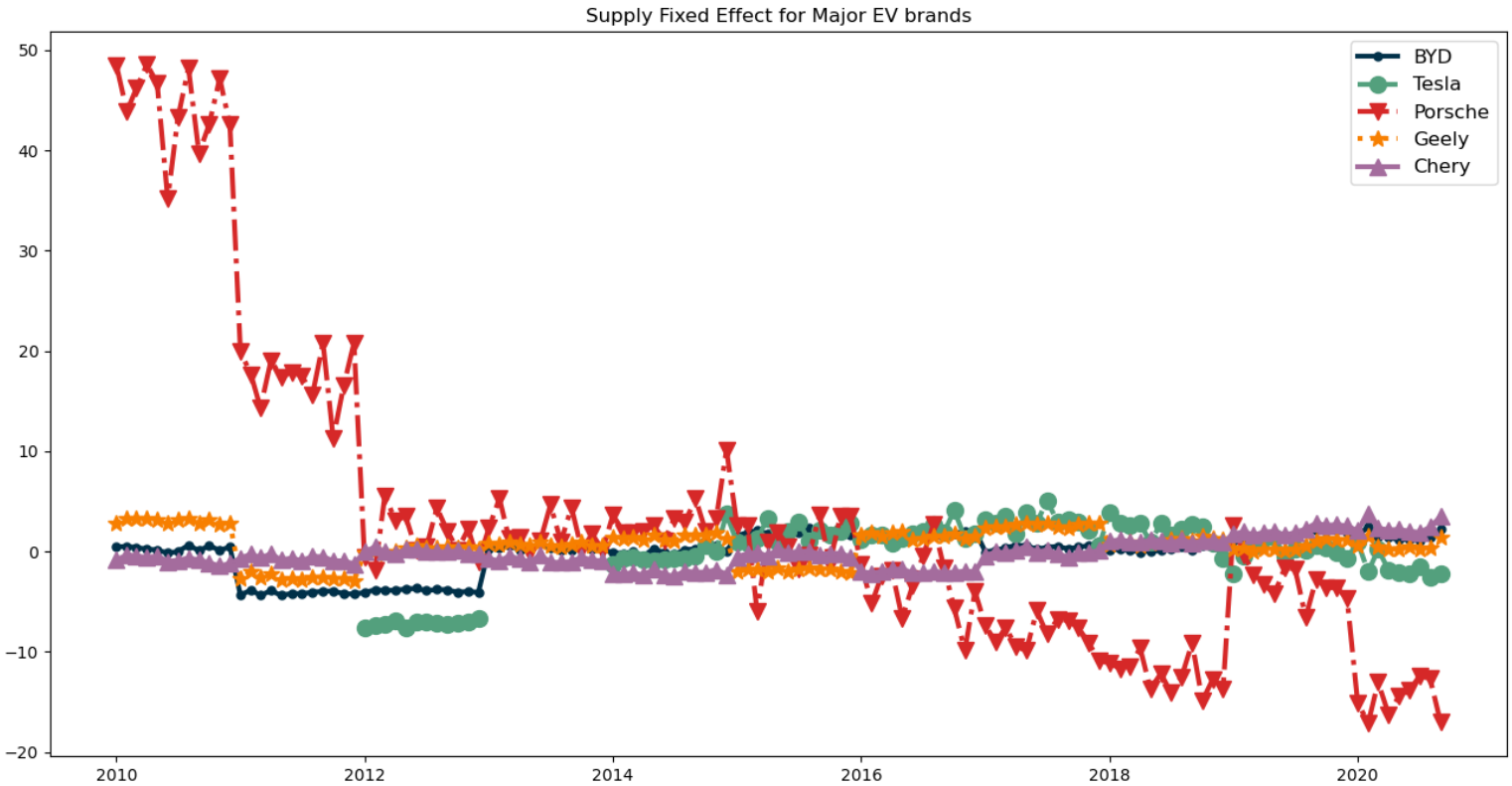

Figure: Estimated Average Supply Shocks

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Gandhi, A., Lu, Z., and Shi, X. (2019). Estimating demand for differentiated products with zeroes in market share data. *Available at SSRN 3503565*.

Garrido, F. (2020). An aggregative approach to price equilibrium among multi-product firms with nested demand. *Available at SSRN 3647311*.