Development and Adoption of Plug-in Electric Vehicles in China

Presented by:
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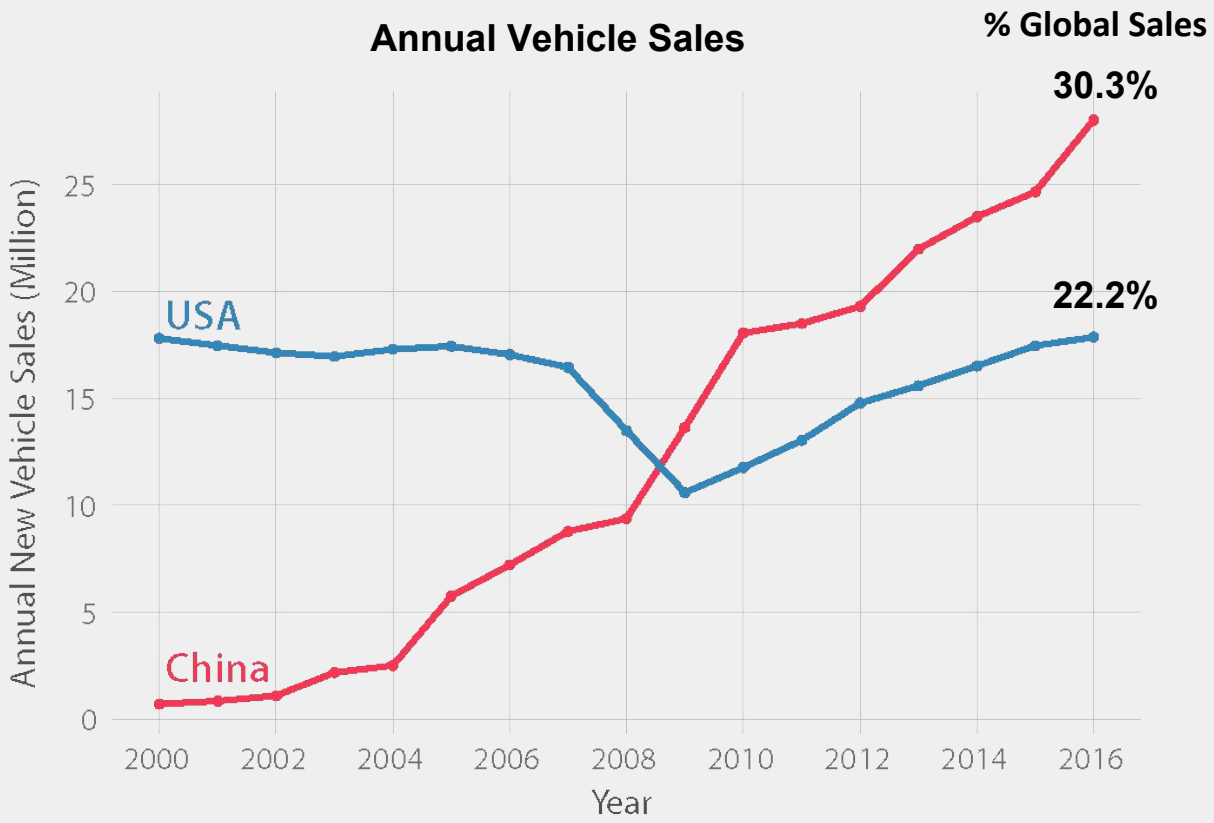
October 02, 2017

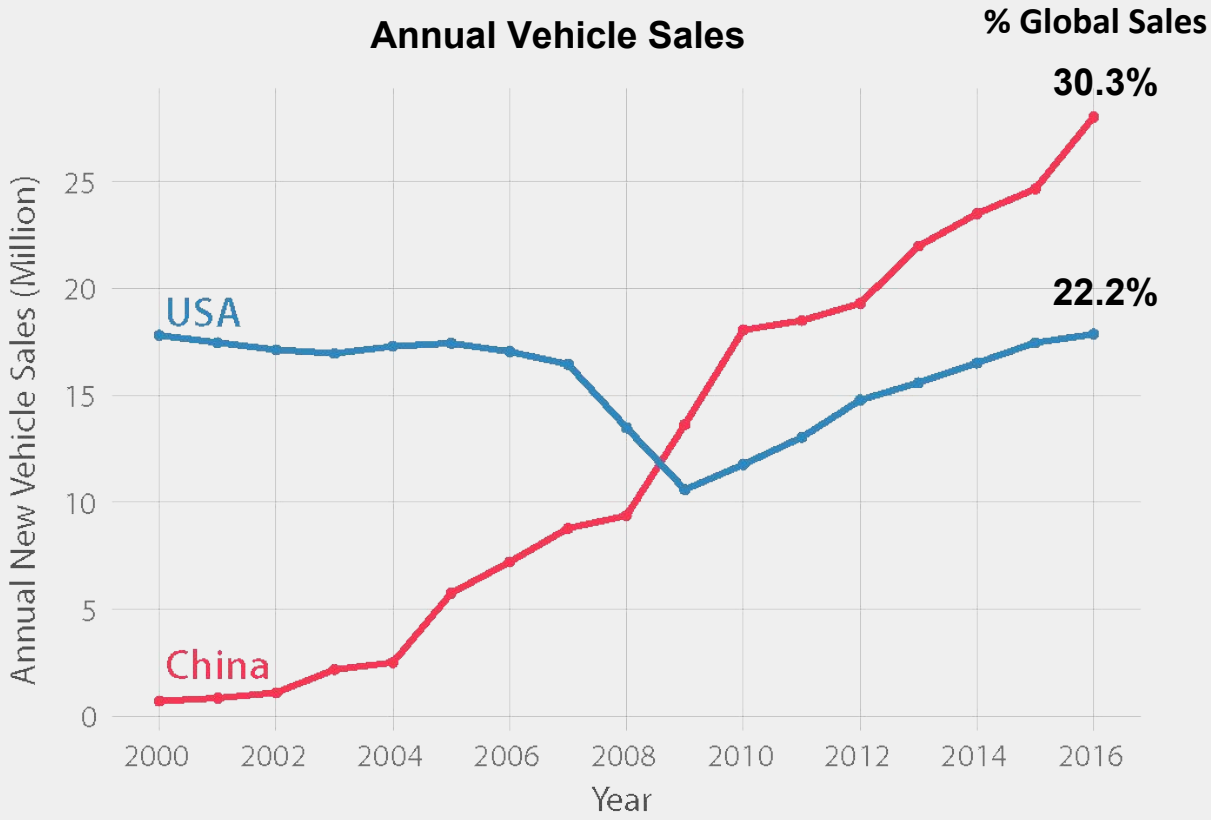
China: World's largest vehicle market

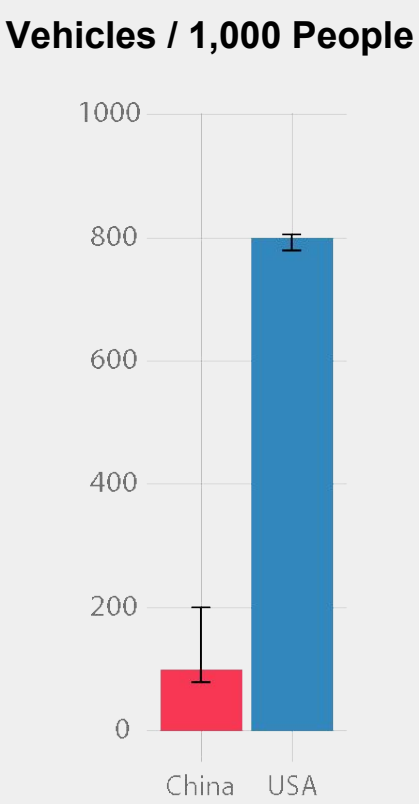


OICA: http://www.oica.net/category/sales-statistics/

National Bureau of Statistics of China: http://www.stats.gov.cn/tjsj/ndsj/2014/indexeh.htm; U.S. FHWA. Licensed Drivers, Vehicle Registrations, and Resident Population

China: World's largest vehicle market…with room to grow





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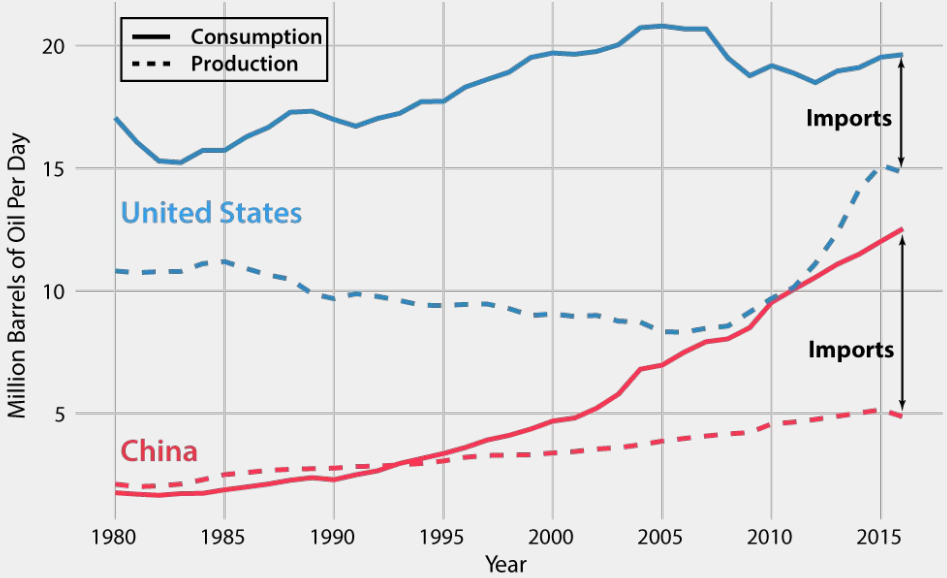
Potential of Electric Vehicles:

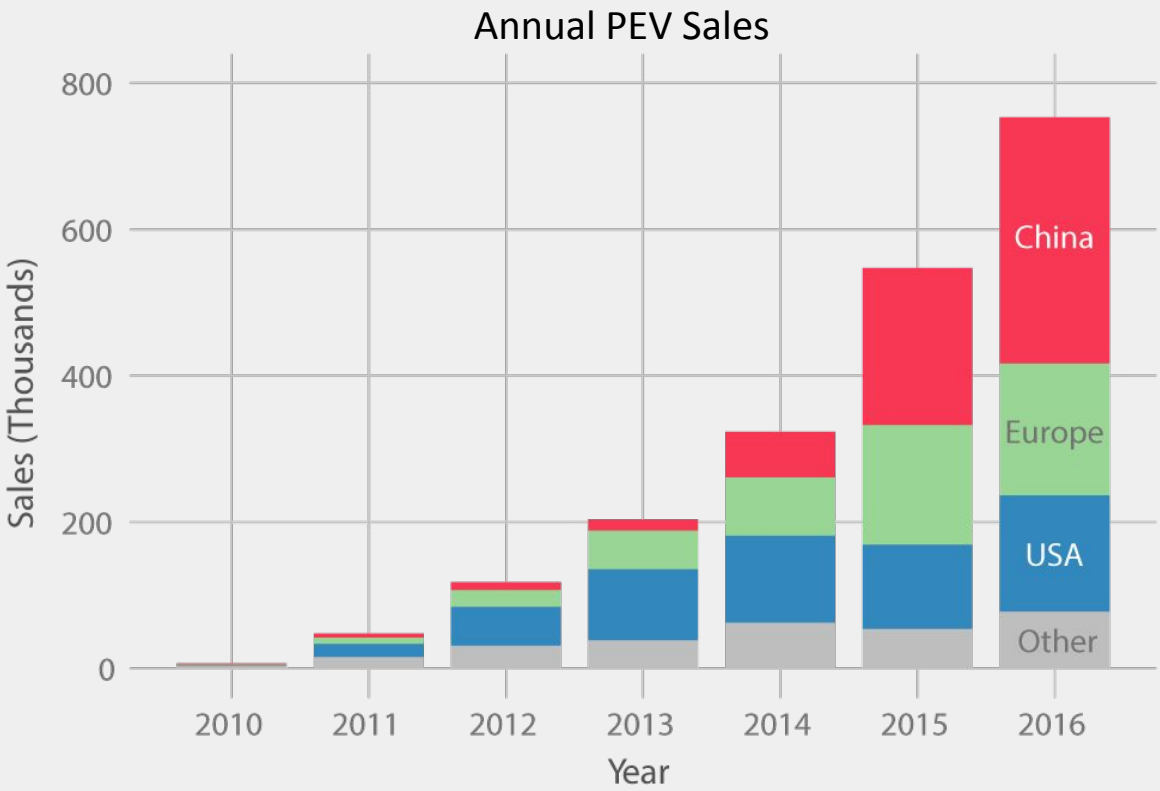
- Reduce Oil Dependence
- Reduce Pollution
- Technological Leadership



U.S. EIA: https://www.eia.gov/petroleum/data.php

One week in Beijing, Oct. 2016

2016: 45% of world's electric vehicles sold in China



Source: http://www.ev-volumes.com

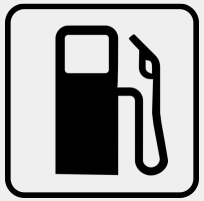
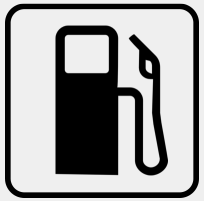
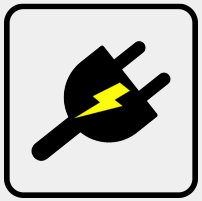
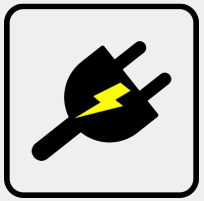
Dissertation Research Question:
What factors are are shaping the **development** and **adoption** of plug-in electric vehicles (PEVs) in China?

Main Findings:

1. **Adoption:**
   Chinese car buyers may be more willing to adopt full electric vehicles than Americans.
   Published at *Transportation Research Part A: Policy & Practice* (2015)
2. **Development:**
   Domestic Chinese firms sold 95% of 2016 PEV sales in China, and they are experimenting with a wide variety of innovations.
   Second R&R at *Research Policy*

"EV" Taxonomy

Plug-in Electric Vehicles (PEVs)

	CV (Conventional)	HEV (Hybrid)	PHEV (Plug-in Hybrid)	LSEV (Low-Speed EV)	BEV (Battery Electric)
					
Power Converter:	Engine	Engine + Motor	Engine + Motor	Motor	Motor
Battery Pack:	--	Small; Li-ion	Medium; Li-ion	Medium; Lead-acid	Large; Li-ion

Will Subsidies Drive Electric Vehicle Adoption? Measuring Consumer Preferences in the U.S. and China

Published at *Transportation Research Part A: Policy & Practice* (2015)

Research Questions:

1. What are consumers' preferences towards electric vehicles in the U.S. vs. China?
2. How do these consumer preferences shape adoption of electric vehicles?

Helveston, J. P., Y. Liu, E. M. Feit, E. Fuchs, E. Klampfl, J.J. Michalek (2015) "Will subsidies drive electric vehicle adoption? Measuring consumer preferences in the U.S. and China." *Transportation Research Part A: Policy and Practice*, 73, 96–112.

Past Automotive Demand Modeling Literature

Paper	Year	Model Form*	EVs	Conjoint	Data years	Location
Boyd & Mellman	1980	MNL, MXL			1977-1978	USA
Goldberg	1995	NL, MNL			1989-1990	USA
Berry, Levinsohn, & Pakes	1995	MNL, MXL			1971-1990	USA
McCarthy	1996	MNL			1983-1985	USA
Golob et al.	1997	P	x	x	1994	USA
Goldberg	1998	NL, MNL		x	1993	USA
Brownstone & Train	1999	MNL, MXL, P	x	x	1993	USA
Brownstone, Bunch, & Train	2000	MNL, MXL	x	x	1993	USA
McFadden & Train	2000	MXL	x	x	1993	USA
Sudhir	2001	MXL			1981-1990	USA
Choo & Mokhtarian	2004	MNL		x	1998	USA
Berry, Levinsohn & Pakes	2004	MXL			1993	USA
Santini & Vyas	2005	MNL	x	x	1998-2002	USA
Train and Wilson	2007	MXL			2000	USA
Dagsvik and Liu	2009	NL		x	2001	Shanghai
Axsen, Mountain, Jaccard	2009	MNL	x	x	2006	USA & Canada
Axsen, Kurani	2009	--	x		2007	USA
Ziegler	2012	P	x	x	2007-2008	Germany
This Study	2015	MNL, MXL	x	x	2012	USA & China

*MNL = Multinomial Logit, NL = Nested Logit, MXL = Mixed Logit, P = Probit

SECTION 3

Each option will look like this:

Suppose these 3 vehicles below were the only vehicles available for purchase, which would you choose?

Attribute*	Option 1	Option 2	Option 3
Vehicle Type	Conventional 300 mile range on 1 tank	Plug-In Hybrid & 300 mile range on 1 tank (first 40 miles electric)	Electric 75 mile range on full charge
Brand	German	American	Japanese
Purchase Price	$18,000	$32,000	$24,000
Fast Charging Capability	--	Not Available	Available
Operating Cost (Equivalent Gasoline Fuel Efficiency)	19 cents per mile (20 MPG equivalent)	12 cents per mile (30 MPG equivalent)	6 cents per mile (60 MPG equivalent)
0 to 60 mph Acceleration Time**	8.5 seconds (Medium-Slow)	8.5 seconds (Medium-Slow)	7 seconds (Medium-Fast)
	○	○	○

*To view an attribute description, click on:

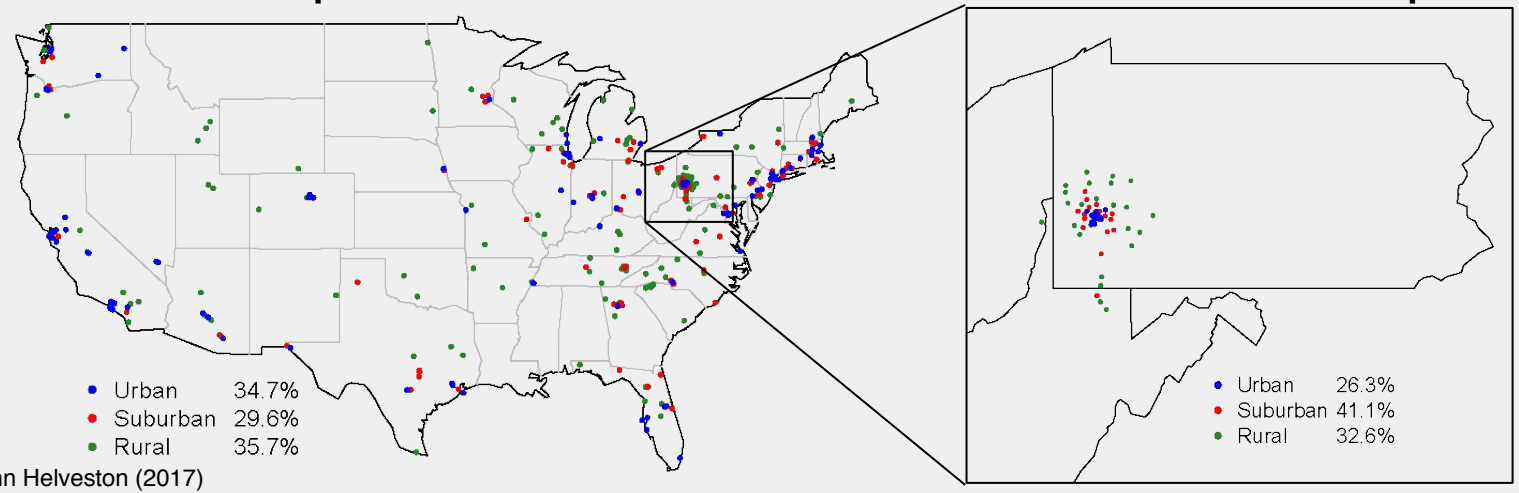
**The average acceleration for cars in the U.S. is 0 to 60 mph in 7.4 seconds

Same survey, calibrated to U.S. & Chinese markets

China Sample

	China	U.S.
Fielding Dates:	July 2012	Sept. 2012 Feb. 2013
Respondents:	448	384
Choice Observations:	6,720	5,760

U.S. Online Sample



U.S. Auto Show Sample

Weights added to match car-buying demographic

Sample demographics compared to new car buyer survey by Ford

Variable	U.S.			China		
	Our Sample	Weighted Sample	Ford Sample	Our Sample	Weighted Sample	Ford Sample
Household Income	57.3 (29.3)	74.3 (28.7)	74.8 (27.3)	24.1 (15.7)	26.1 (18)	26.1 (17.6)
Age	33.9 (12.7)	51 (14.8)	53.1 (15.4)	33.3 (10.6)	34.8 (7.8)	35.1 (7.8)
Num Children	0.6 (1.1)	1.4 (1.4)	0.4 (0.8)	0.6 (0.6)	0.7 (0.6)	0.7 (0.6)
Num Vehicles	1.8 (0.8)	2 (0.7)	--	0.4 (0.6)	0.5 (0.7)	--
Daily VMT	22.9 (10.4)	23.3 (11.4)	--	--	--	--
Annual VMT	11,200 (4,800)	12,500 (4,600)	11,400 (6,400)	--	--	10,600 (6,000)
Household Size	2.7 (1.3)	2.7 (1.2)	2.5 (1.2)	3.3 (1.1)	3.3 (1.2)	3.2 (1)
Years Education	7.2 (1.9)	7.9 (2.3)	7.2 (2.3)	5.9 (1.9)	6 (1.8)	5.9 (2)
Percent Female	35.3%	32.6%	39.3%	39.4%	41.1%	28.7%
Percent Married	44.6%	68.9%	73.5%	55.1%	70.2%	85.6%
Percent with No Children	72.1%	40.3%	75.0%	52.2%	36.5%	36.4%
Percent College Graduates	52.3%	71.2%	53.7%	30.6%	33.1%	34.4%
Percent First Time Buyers	4.4%	1.3%	--	65.4%	59.2%	--
n	384	384	161,903	448	448	13,469

Model choice behavior with random utility model

Model coefficients

Observed attributes

Unobservables

Utility to person *n* from choosing alternative *j:*

$$u_{nj} = \boldsymbol{\beta}_n' \mathbf{x}_j + \varepsilon_{nj} \qquad \varepsilon_{nj} \sim \text{Gumbel}\left(0, \frac{\pi^2}{6}\right)$$

<u>Goal of inference</u>:

Estimate $\boldsymbol{\beta}_n$ to understand how **observable product attributes**, $\mathbf{x}_j$, influence **consumer choices**

Train, K. (2009)

Maximize log-likelihood to estimate model coefficients

Probability of choosing alternative *j*

Maximize log-likelihood to estimate $\boldsymbol{\beta}_n$: $$\underset{\boldsymbol{\beta}}{\text{minimize}} \quad -L = -\sum_n^N \sum_j^J y_{nj} \ln P_{nj}(\boldsymbol{\beta}_n | \mathbf{x}_j)$$

Homogeneous model: $$P_{nj} = \frac{\exp\left(\boldsymbol{\beta}'\mathbf{x}_j\right)}{\sum_{k \in \mathcal{J}} \exp\left(\boldsymbol{\beta}'\mathbf{x}_k\right)}$$

Heterogeneous model: $$P_{nj} = \int \left(\frac{\exp\left(\boldsymbol{\beta}_n'\mathbf{x}_j\right)}{\sum_{k \in \mathcal{J}} \exp\left(\boldsymbol{\beta}_n'\mathbf{x}_k\right)} \right) f(\boldsymbol{\beta}|\boldsymbol{\theta}) d\boldsymbol{\beta}, \qquad \boldsymbol{\beta}_n \sim f(\boldsymbol{\beta}|\boldsymbol{\theta})$$

Estimate Models in "Willingness to Pay (WTP)" Space

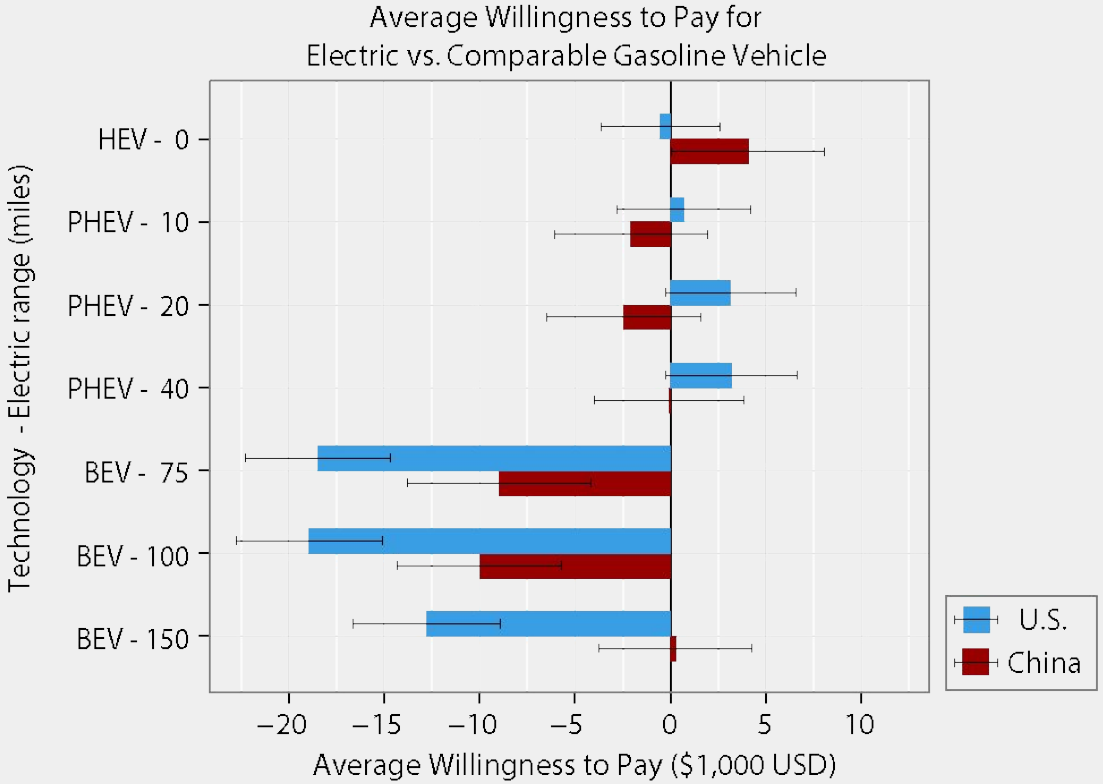
Non-price coefs

Price coef

WTP: $\boldsymbol{\omega}_n = \boldsymbol{\beta}_n / \alpha_n$

Model Space	Model Specification	Parameter of interest	Units
Preference:	$u_{nj} = \boldsymbol{\beta}_n' \mathbf{x}_j - \alpha_n p_j + \varepsilon_{nj}$	$\boldsymbol{\beta}_n$	"Utility"
WTP:	$u_{nj} = \alpha_n \left(\boldsymbol{\omega}_n' \mathbf{x}_j - p_j \right) + \varepsilon_{nj}$	$\boldsymbol{\omega}_n$	Currency ($)

Chinese Consumers More Receptive to Today's Full Electric Vehicles Than American Consumers

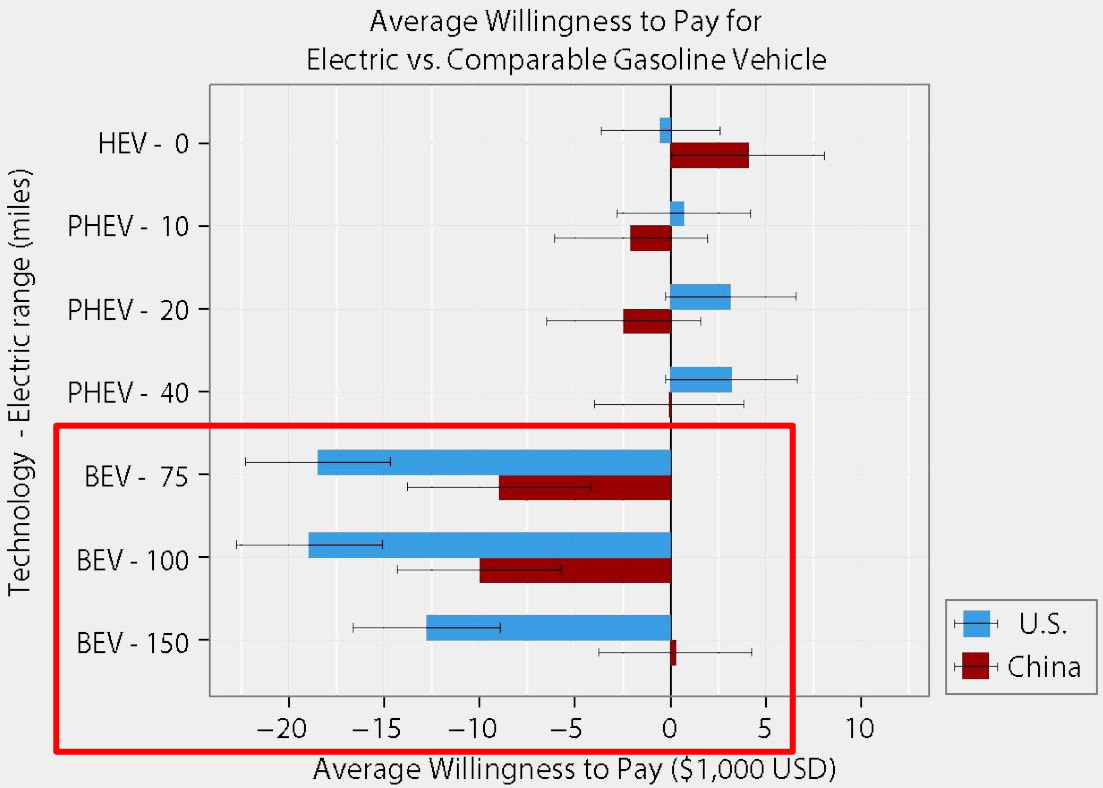


Chinese Consumers More Receptive to Today's Full Electric Vehicles Than American Consumers

<u>USA</u>
Consumers sensitive to limited electric range

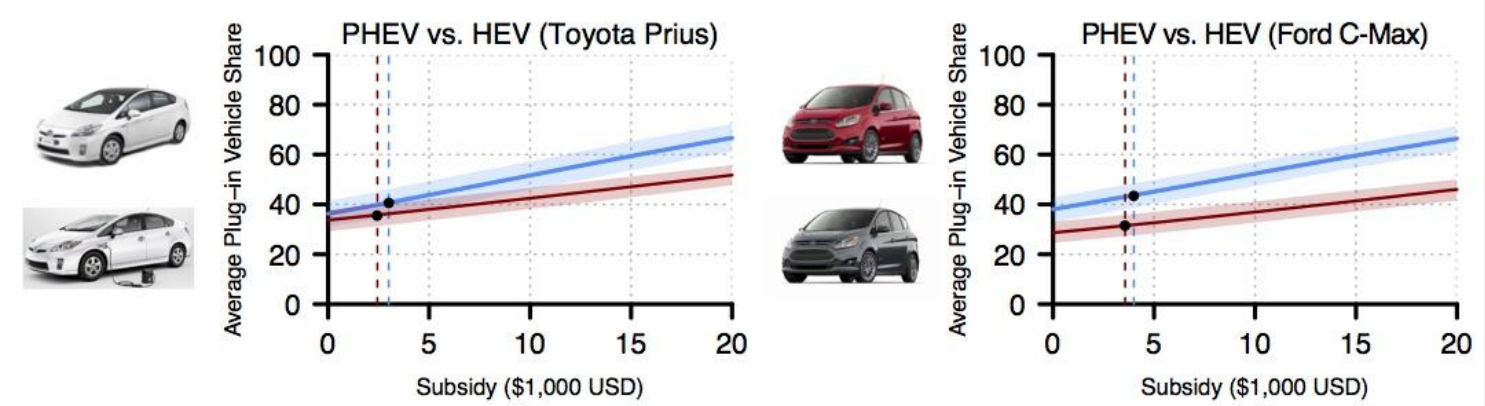
<u>China</u>
Most Chinese are first time buyers

More alternatives for long-distance travel (e.g. high speed rail)

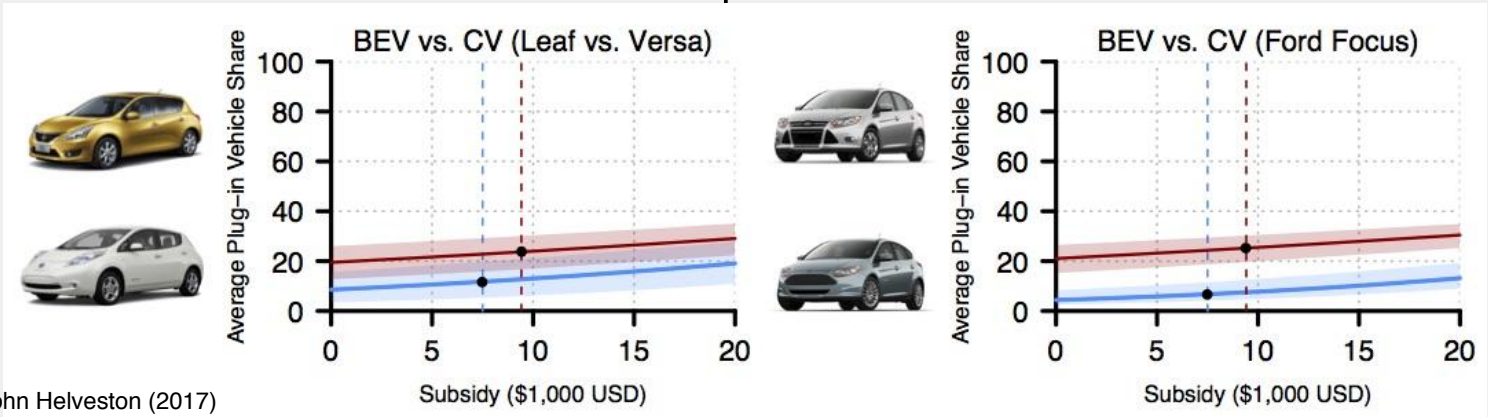


Given current subsidies…

Chinese drivers *less* receptive to **PHEVs** than Americans



Chinese drivers *more* receptive to **BEVs** than Americans



Current Subsidies

Simulation Results

Bands reflect model parameter uncertainty

Summary of Contributions

- First study to directly compare U.S. & China consumer preferences for PEVs.
- On average, Chinese respondents more receptive to BEVs than American respondents, regardless of subsidies.

<u>Potential Implications</u>:

☑ Reduce oil dependence

? Reduce pollution? (might increase <u>local</u> emissions)

? Technology leadership? (decrease <u>global</u> emissions)

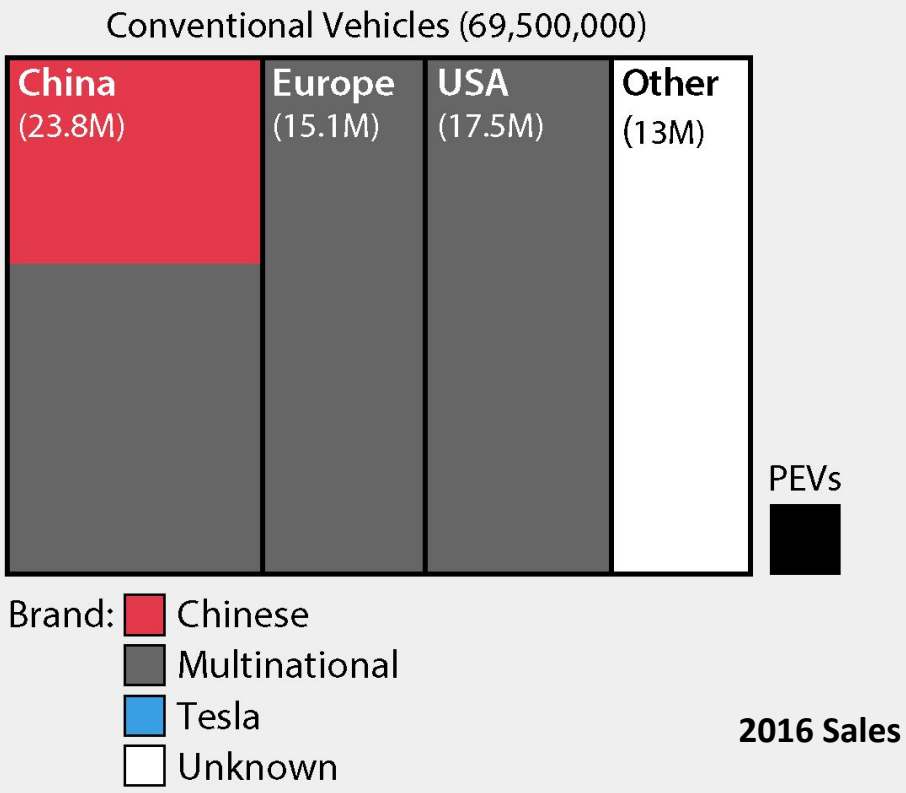
→ global incentives for PEV R&D investment →
→ global PEV adoption →
→ reduced global emissions?

Innovating Up, Down, and Sideways: The (Unlikely) Institutional Origins of Experimentation in China's Plug-in Electric Vehicle Industry

Second R&R at *Research Policy*

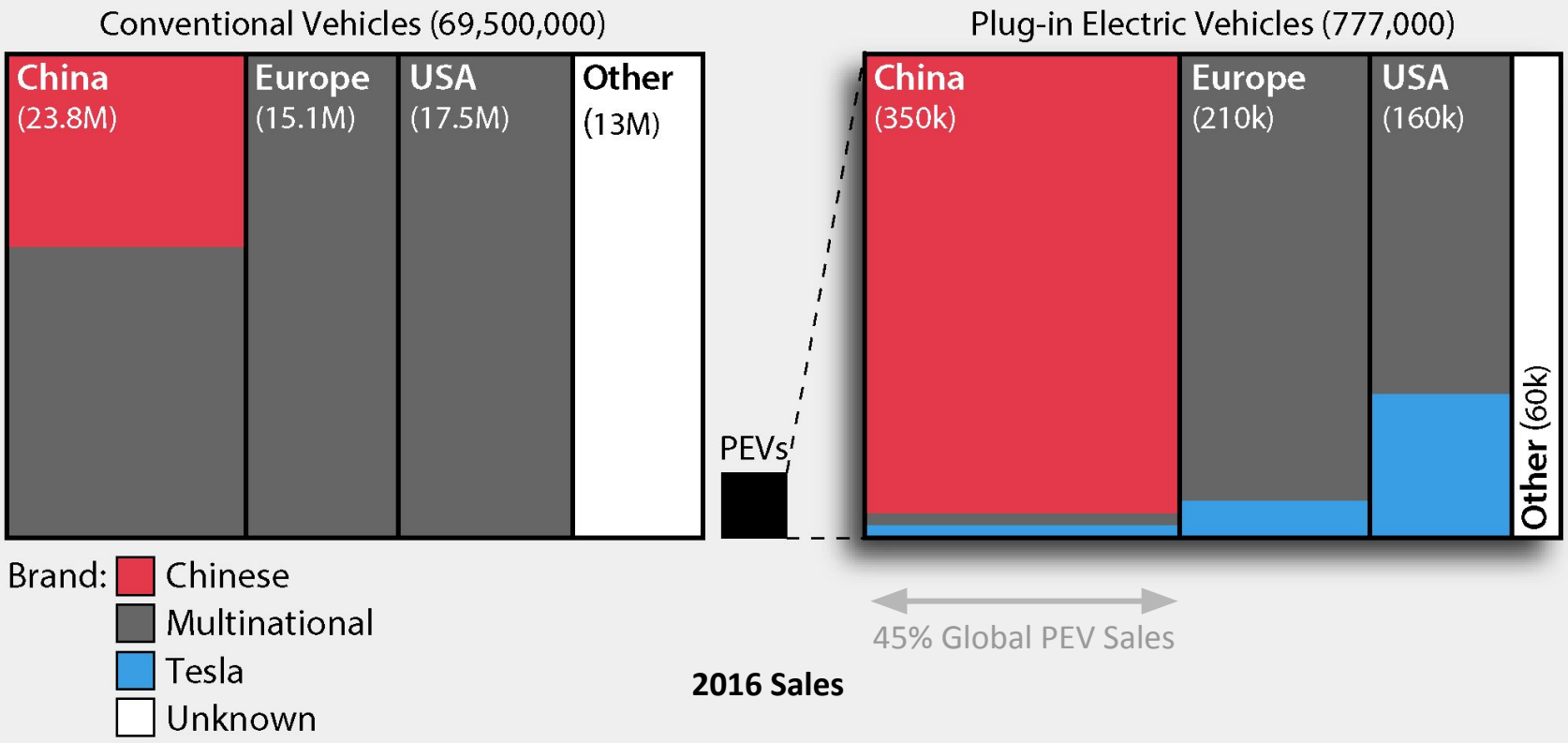
Helveston, J.P., Y. Wang, V.J. Karplus, and E. R.H. Fuchs "Innovating Up, Down, and Sideways: The (Unlikely) Institutional Origins of Experimentation in China's Plug-in Electric Vehicle Industry," Under Review at *Research Policy*.

Global Conventional Vehicle Sales: Multinationals Dominate



Data scraped from: 1) https://www.gasgoo.com 2) https://www.carsalesbase.com

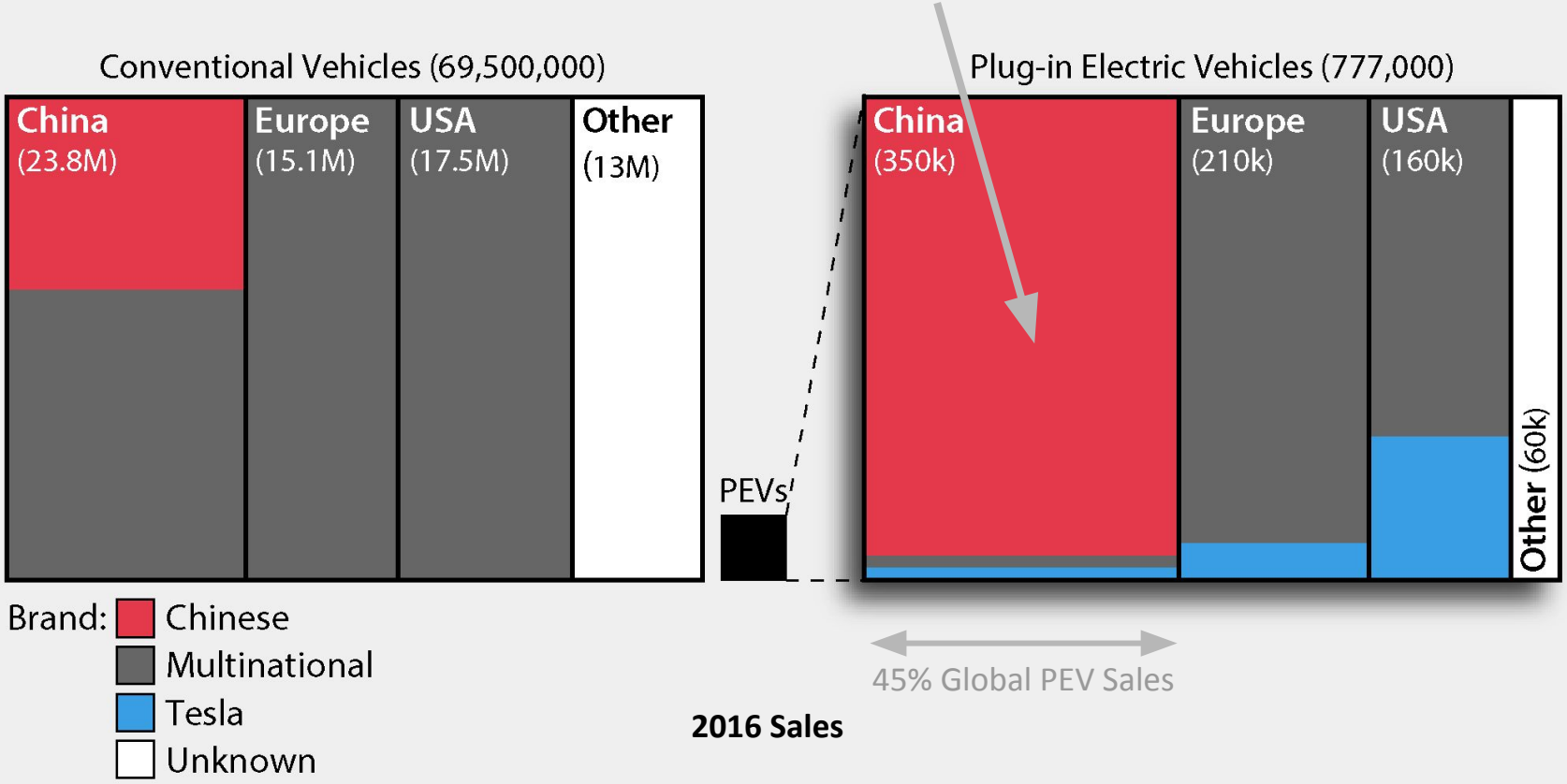
Global PEV Sales: Chinese Firms Dominate



2016 Sales

Data scraped from: 1) https://www.gasgoo.com 2) https://www.carsalesbase.com

Research Question:
Why are (independent) Chinese firms leading China's PEV market?



Data scraped from: 1) https://www.gasgoo.com 2) https://www.carsalesbase.com

Inductive grounded theory-building

Vehicle Sales Data

China: Monthly by Make & Model (2003 – 2016)
1: CAAM yearbooks
2: Webscraped: Gasgoo.com

U.S. & Europe: Annual by Make (2016)
1: carsalesbase.com
2: hybridcars.com

Archival Data

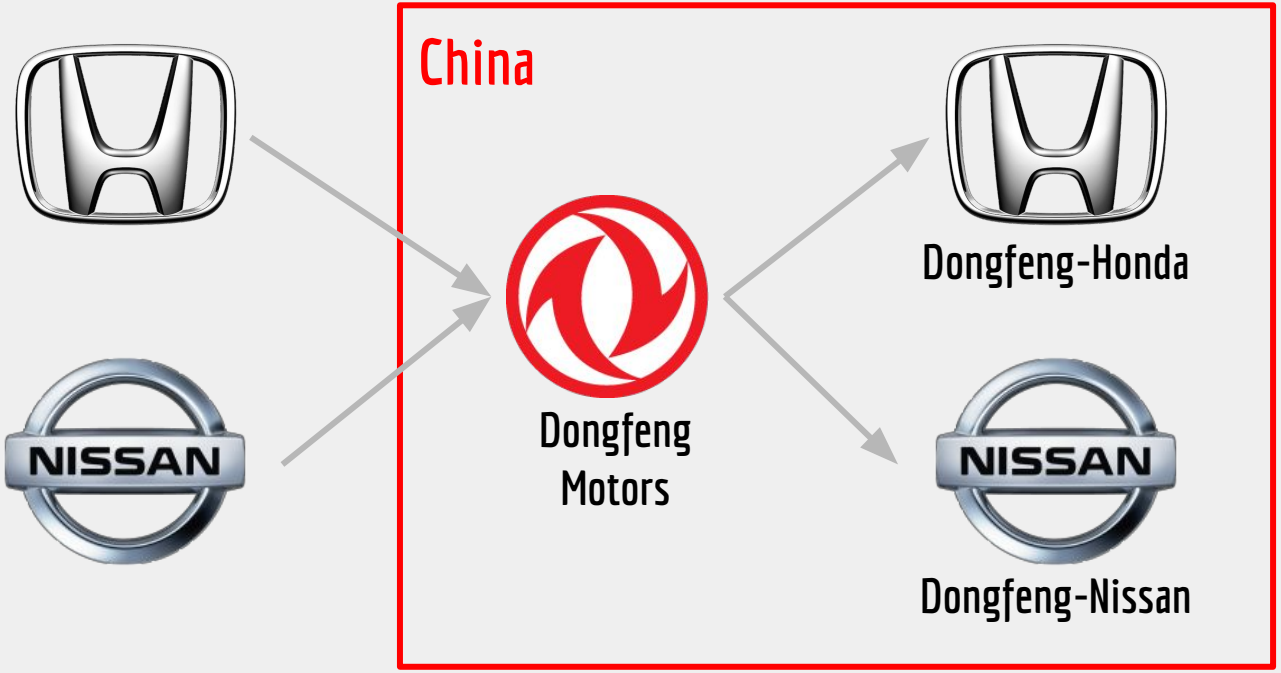
112 unique documents
3,215 pages of content

51 Interviews

27 - Four Case Study firms
10 - JV firms
4 - Universities
4 - Consultants
3 - Non-profits
2 - Gov't Officials
1 - Reporter

The Chinese Joint Venture System

1980s: 以市场换技术 = “Exchange market for technology”



Past research suggests system has largely failed to transfer technology

(Brandt & Thun, 2010; Feng, 2010; Howell, 2016; Huang, 2003; Lazonick & Li, 2012; Nam, 2011)

PEVs must be made / developed in China to get subsidies

To get subsidies, one of these must be made / developed in China:

Battery | Motor | Control System

Nissan → X

Nissan *Leaf*

China

Dongfeng Motors

Dongfeng-Nissan

Venucia *Morning Wind*

Foreign OEMs won't bring most advanced PEV technologies to JVs

"Selling gas cars makes money! The business case (for EVs) is weak. Margins (for CVs) in China are around 10%!"
- Former manager for JV firm

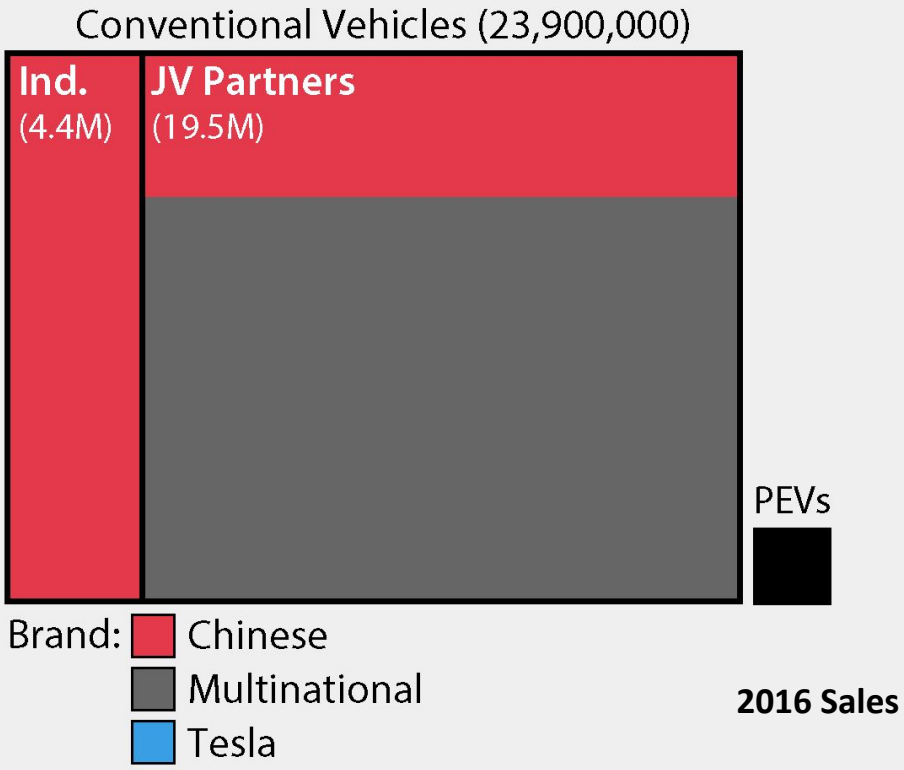
"So when [MNE] and [JV partner] decided to do the [BEV], they thought, 'Well, okay, we won't make any money on it...but we will check the box and say we have built a 'new energy vehicle' in China and we're now selling it.'"
- Former manager for JV firm

Chinese JV partners lack incentives to independently innovate

"It's like opium. Once you've had it you will be addicted forever."
- Guangyuan He, Former Minister of Machinery and Industry (Reuters, 2012)

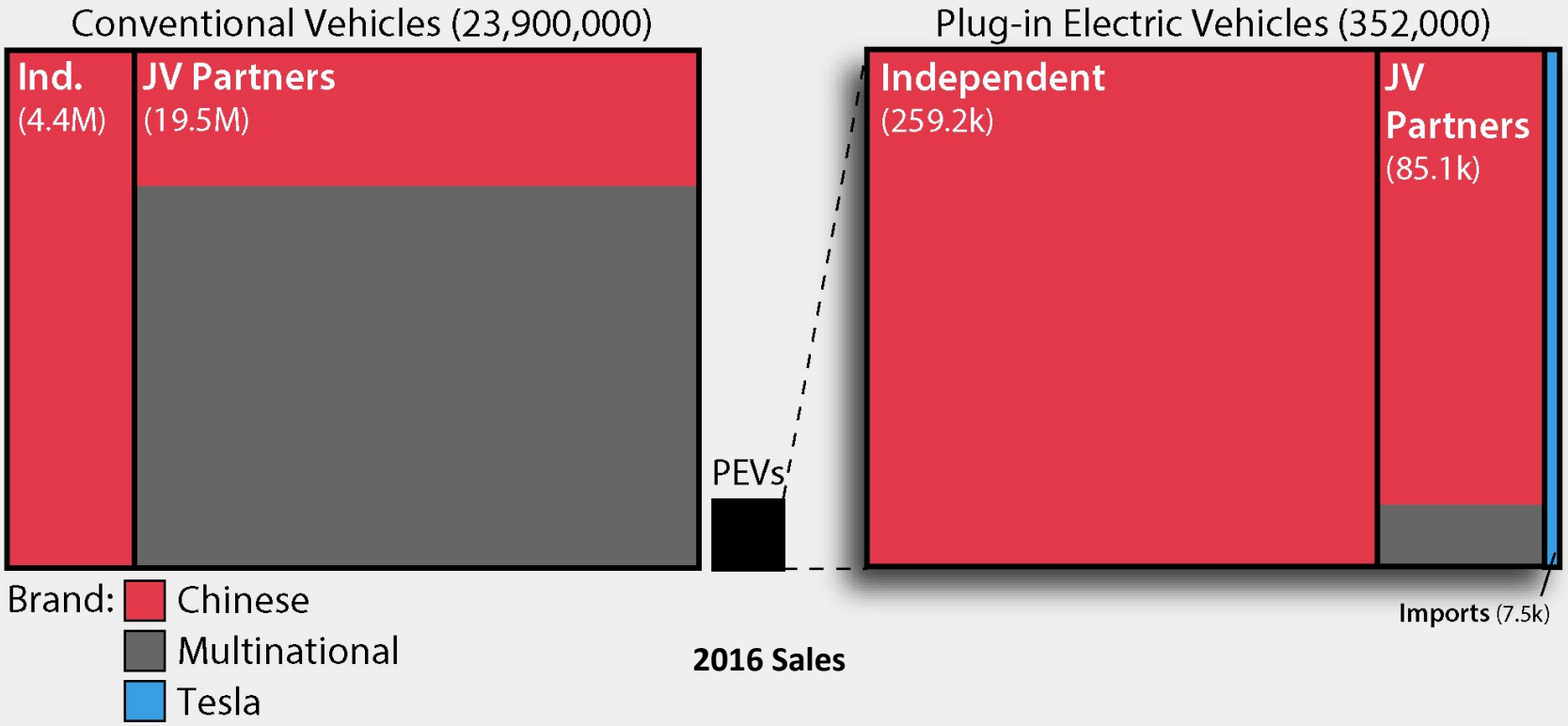
"[JV partners] like SAIC, Dongfeng, FAW...they don't have pressure to make EVs and improve their own brand image like BYD does. They're only focused on gas vehicles."
- Marketing manager for large JV

China Conventional Vehicle Sales: Multinationals Dominate



Data scraped from: https://www.gasgoo.com

China PEV Sales: Independent Chinese Firms Dominate (Not Chinese JV partners)



Data scraped from: https://www.gasgoo.com

Existing Theory

New Theory

Limiting
indigenous innovation
in *established* industry

(Brandt & Thun, 2010; Feng, 2010; Howell, 2016; Huang, 2003; Lazonick & Li, 2012; Nam, 2011)

JV System

Enabling
indigenous innovation
in *emerging* industry

China's Independent PEV Firms: Examples of Experimentation

Chery

脚踏实地

Stepping on solid ground

Shared BEV / CV platform reduces overall BEV production costs; in -house battery design

Jiayuan

存在就是合理的

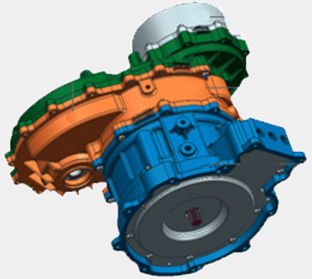
"If it exists, it must be reasonable"[1]

Lower performance components and localized production enables entry into low cost LSEV market

Haike

大巧若拙，大道至简

"Dumbing down is the way up"[2]

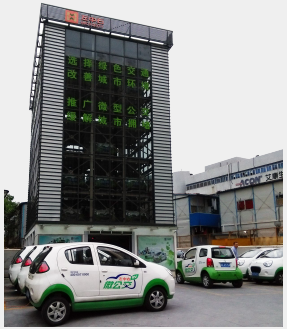


Flywheel energy storage transmission reduces BEV battery and motor performance requirements and cost

Kandi

异曲同工

Different tune, equally melodic



Car sharing business model reduces driving range requirements and enables new refueling approaches

1: Interview #30
2: Interview #27

Cultivating Diverse Experimentation: *Local Institutional Support*

Chery

脚踏实地

Stepping on solid ground

Subsidies restricted to locally-produced models

Jiayuan

存在就是合理的

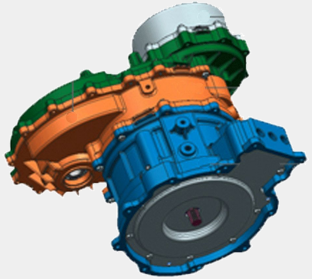
"If it exists, it must be reasonable"[1]

Subsidized production facilities; operation in regulatory "gray area"

Haike

大巧若拙，大道至简

"Dumbing down is the way up"[2]

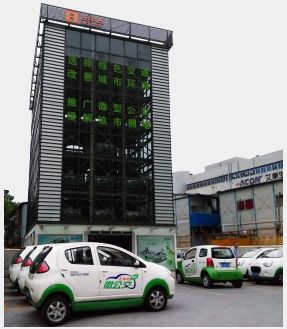


Free office & pilot production facilities

Kandi

异曲同工

Different tune, equally melodic



Subsidized charging infrastructure; local subsidies for BEVs

1: Interview #30
2: Interview #27

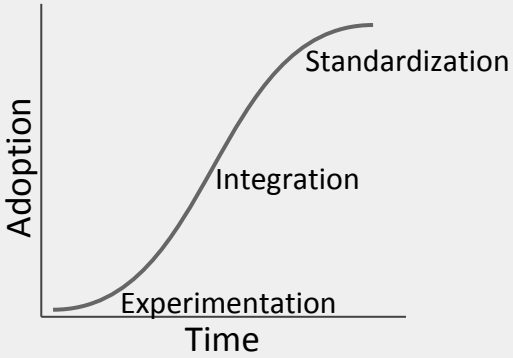
Existing Theory

Experimentation in early phases of R&D important...

(Nelson, 1961; Scherer, 2011)

...but ultimately must transition from regional to national markets

(Boisot & Meyer, 2008; Meyer, 2008; Wei et al., 2017; Amsden & Chu, 2003; Nelson, 1993)



New Theory

Local Protection: *Supporting* experimentation across PEV industry...

...but might inhibit integration

Thanks!

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This work was funded by: