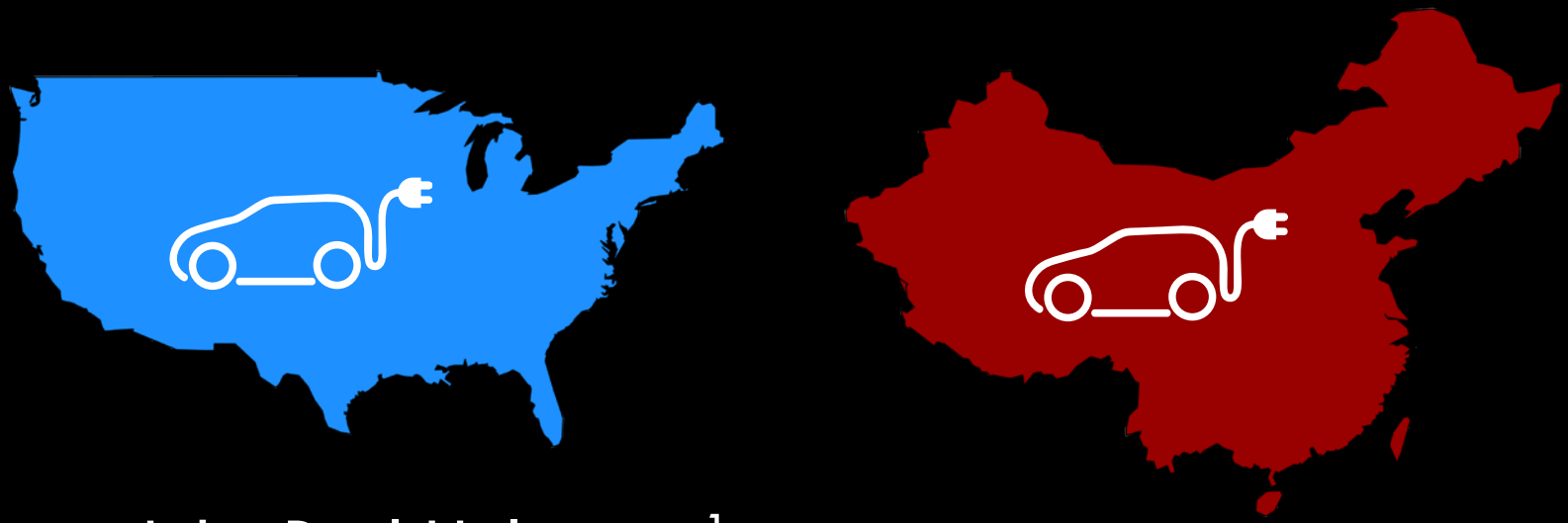
Consumer Preferences for Hybrid and Electric Vehicles in China and the United States: Implications for Policy and Environment



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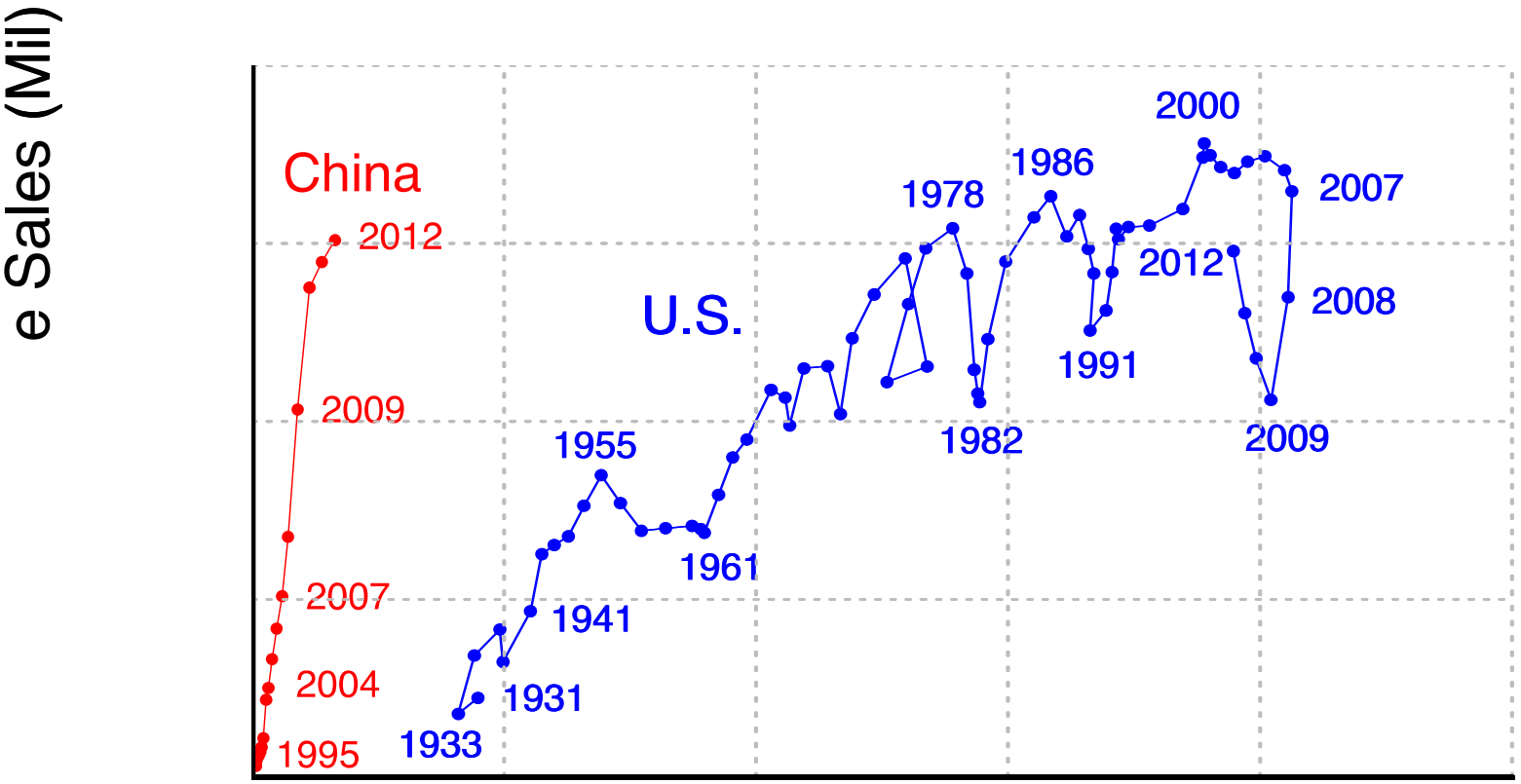
Carnegie Mellon Vehicle Electrification Group

China is the world's largest vehicle market...and growing

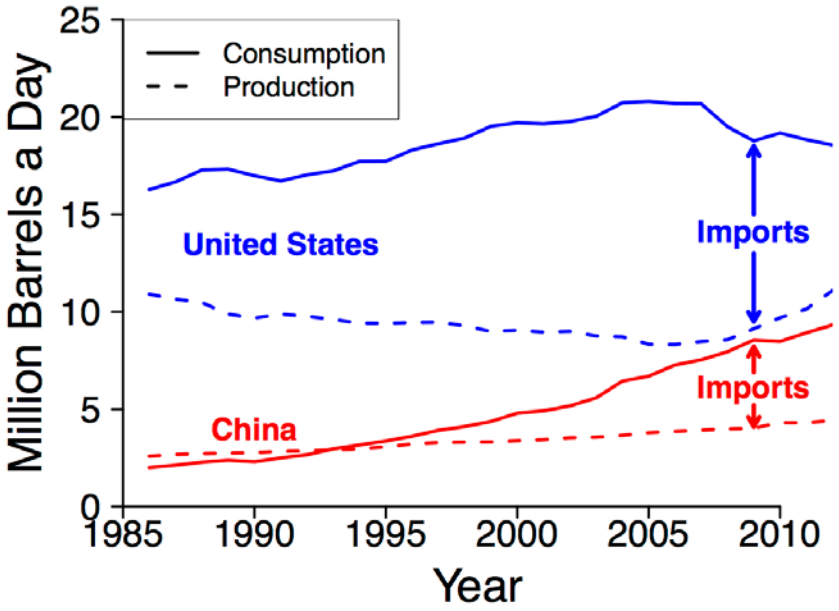


China Statistical Yearbook, 2012
National Bureau of Economic Research
U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2011*

EVs have potential to reduce oil consumption & life cycle emissions

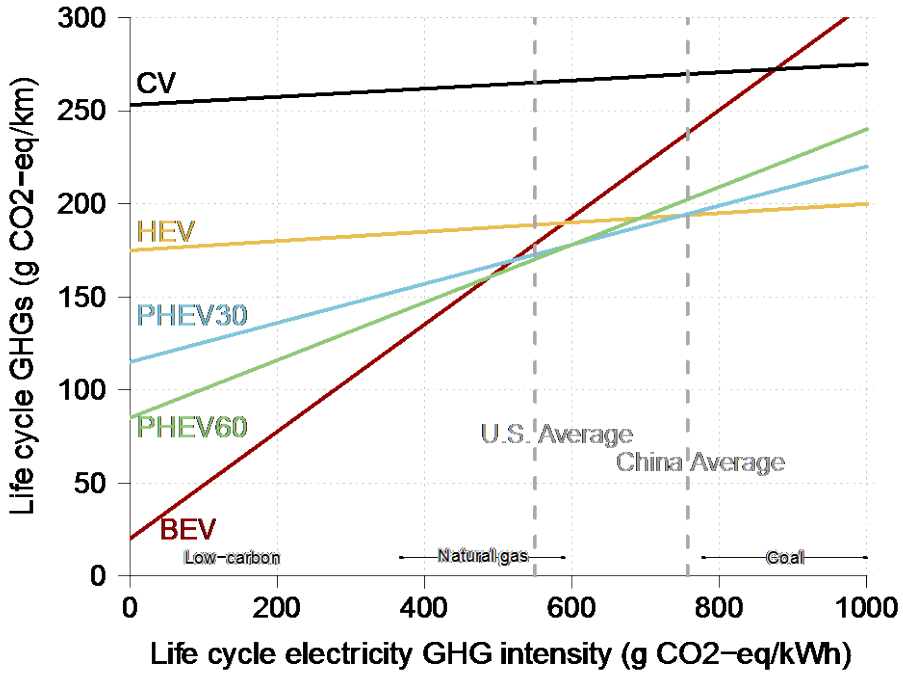
Oil Consumption

- **Problem:** U.S. and China consume ~1/3 of global oil consumption.
- **Impact:**
  - PHEVs expected to use about 40 - 60% less petroleum than conventional vehicles (ANL 2010).
  - BEVs use no oil!



Emissions

- **Problem:** In U.S., cars contribute to 20% of GHG, 40% of VOC, 77% of CO, 50% NOx. In China, similar, even worse for NOx / CO.
- **Impact:** Depends on grid mix; PHEVs have potential to reduce GHG by 32%.[1]



1) Samaras & Meisterling (2008), Environmental Science & Technology. (Figure adapted to include BEV).

Research Questions

- How do existing preferences shape adoption of electrified vehicles in America & China?
  - Under what conditions would mainstream adoption of electrified vehicles occur?
  - What are the implications of these preferences for policy?

Measuring Consumer Preferences

- How do you get data on vehicles that don't exist yet?
- Our Approach: **Choice-Based Conjoint Surveys**

Past Automotive Demand Modeling

Paper	Year	Model Form	Electrified Vehicles	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	**2013**	**MXL**	**x**	**x**	**2012**	**USA & China**

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

SECTION 3

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

Each option will look like this:

Attribute*	Option 1	Option 2	Option 3
Vehicle Type	Hybrid 300 mile range on 1 tank	Plug-In Hybrid & 300 mile range on 1 tank (first 40 miles electric)	Hybrid 300 mile range on 1 tank
Brand	German	American	American
Purchase Price	$32,000	$15,000	$50,000
Fast Charging Capability	--	Available	--
Operating Cost (Equivalent Gasoline Fuel Efficiency)	6 cents per mile (60 MPG equivalent)	19 cents per mile (20 MPG equivalent)	12 cents per mile (30 MPG equivalent)
0 to 60 mph Acceleration Time**	7 seconds (Medium-Fast)	8.5 seconds (Medium-Slow)	8.5 seconds (Medium-Slow)
	○	○	○

*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

China Fielding: Jul. 16 – Aug. 16, 2012

448 Respondents
15 Choice Questions Each
6,720 Choice Questions

- On the ground
- Partnered with State Information Center to field on the ground in China
- Targeted 4 major cities: Beijing, Shanghai, Shenzhen, & Chengdu
  - Tier 1 cities
  - Largest car markets
  - Not rural
  - Gov't focus for EVs
  - Geographically diverse
  - 35% of 2010 total sales

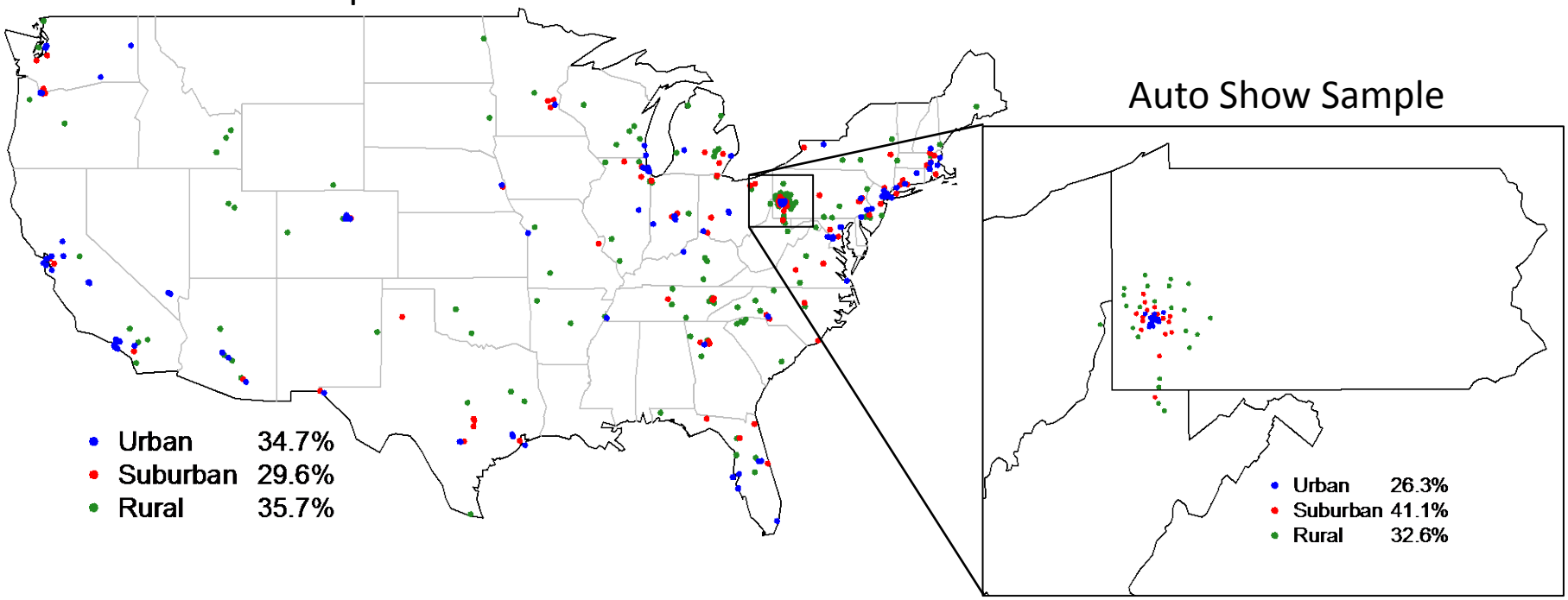
U.S. Fielding: Sept. 2012 & Feb. 2013

amazonmechanical turk beta **& Pittsburgh Auto Show**

283 Online Respondents
101 Auto Show Respondents
15 Choice Questions Each
5,760 Choice Questions

- Online car buyers identified through short screener survey, compensated $2.00.
- Auto show car buyers taken at random, compensated with iPod raffle.

Full Sample



Weights added to match car-buying demographic

Sample demographics compared to large new car buyer survey by Maritz (supplied by Ford)

Variable	U.S.			China		
	Our Sample	Weighted Sample	Maritz Sample	Our Sample	Weighted Sample	Maritz 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

Discrete Choice Models: Linking Attributes to Choice

Automotive Demand Modeling

Random Utility Model:

Estimated partworth utility weight

Observed attributes

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

$$= U_{nj} = \beta' x_{nj} + \varepsilon_{nj}$$

Unobservables

Goal of inference: To understand the **relationship between product attributes** and **purchase proclivity**

Use mixed logit model to link attributes to choice

Logit Model

- Estimates <u>average</u> weights for entire population.

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}}$$

Mixed Logit Model

- Estimates <u>distribution</u> of weights across population.

$$P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) \phi(\beta \mid b, W)\, d\beta$$

P_{ni} = Probability of choosing an alternative from the set of choices.

β = Relative weight of attribute.

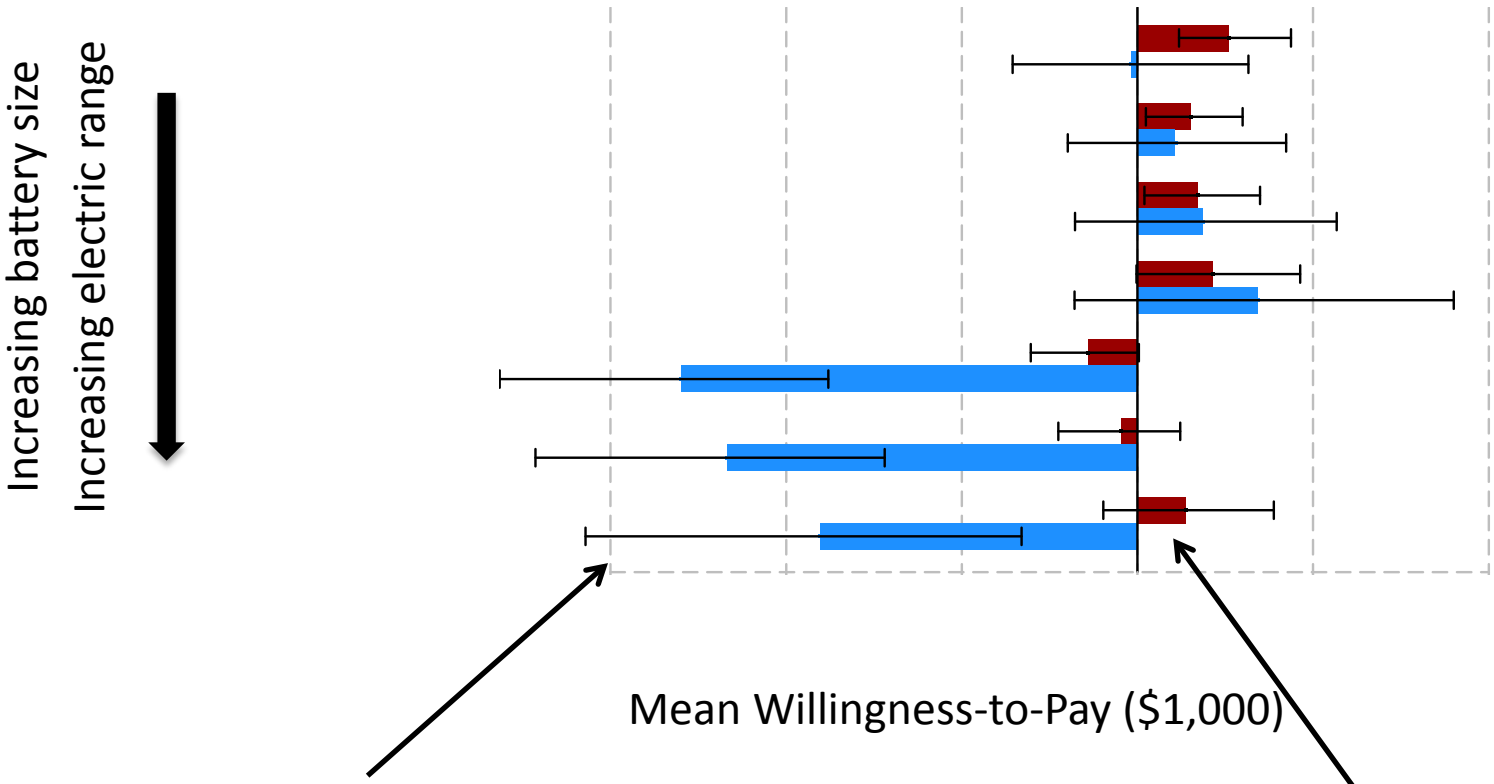
x_{ni} = Attribute of alternative.

*Berry, Levinsohn, & Pakes (1995)
Brownstone & Train (1999)
McFadden & Train (2000)

U.S. more opposed to BEVs than China

$$WTP = \frac{\beta_{att}}{\beta_{price}}$$

Vehicle Technologies



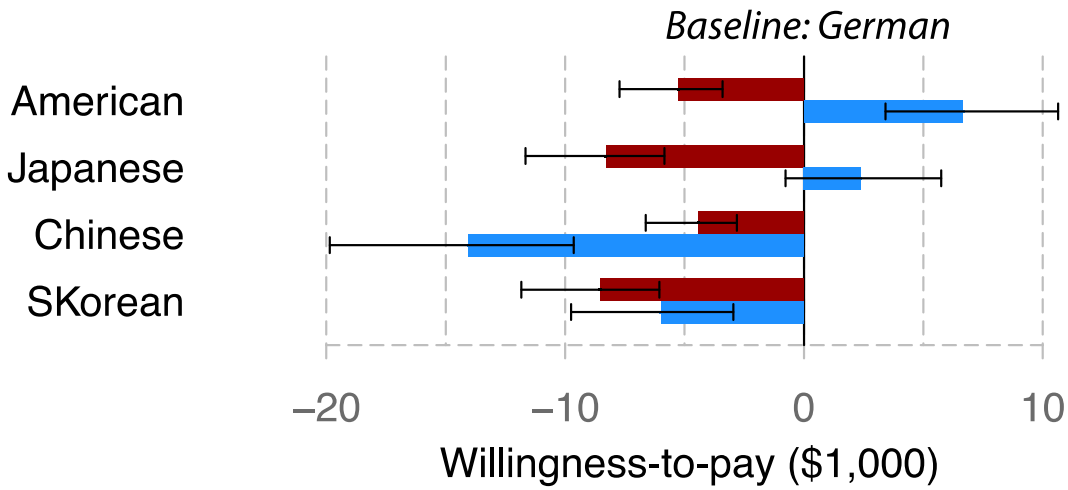
U.S. consumers sensitive to limited electric range (Axsen & Kurani, 2012).

- Most Chinese are first-time car buyers.
- Chinese more familiar with plug-in vehicles (200 – 300 million e-bikes currently on the ground).

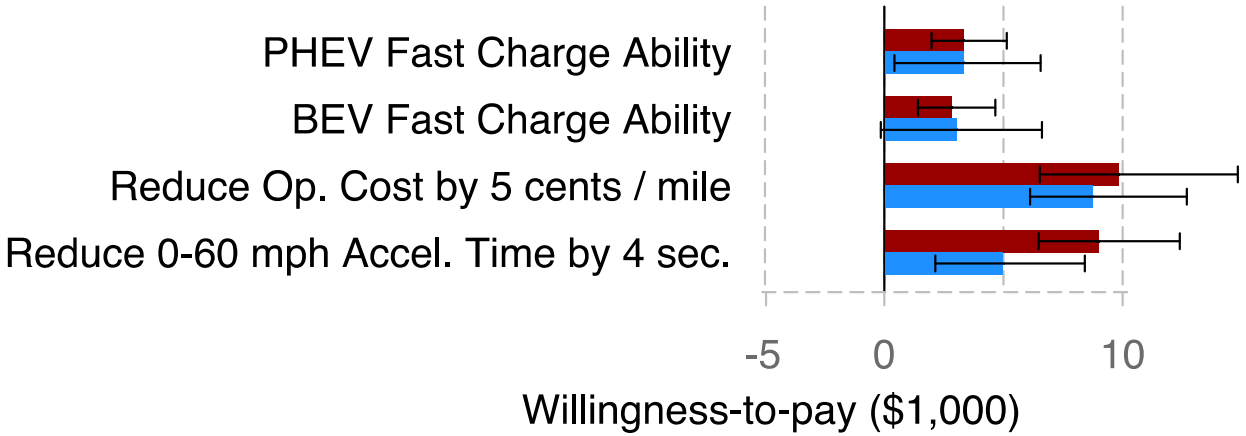
Brand, Fuel Economy, & Acceleration Important

$$WTP = \frac{\beta_{att}}{\beta_{price}}$$

Brand



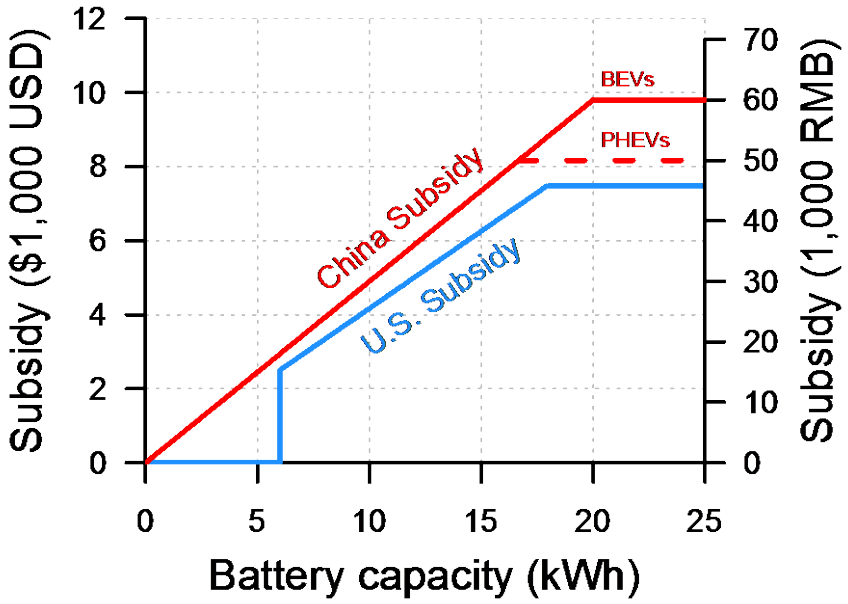
Performance



Under what conditions would a plug-in vehicle gain comparable market share against it's gasoline counterpart ?

photos from motortrend.com

Attribute	CV Focus	BEV Focus
Price	$19,000	$40,000
Type	CV	BEV100
Brand	American	American
Op. Cost (cents/mile)	12	3.5
0-60 mph Acceleration Time	8.9	9.6
Federal Subsidy	--	U.S.: $7,500 China: $9,400

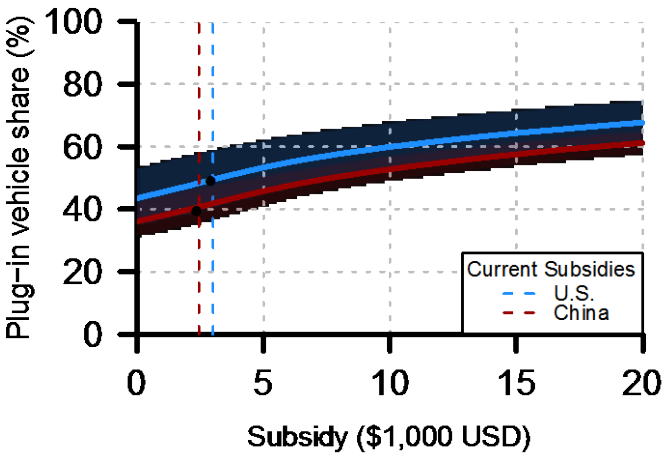


Subsidies play an important role in plug-in vehicle attractiveness

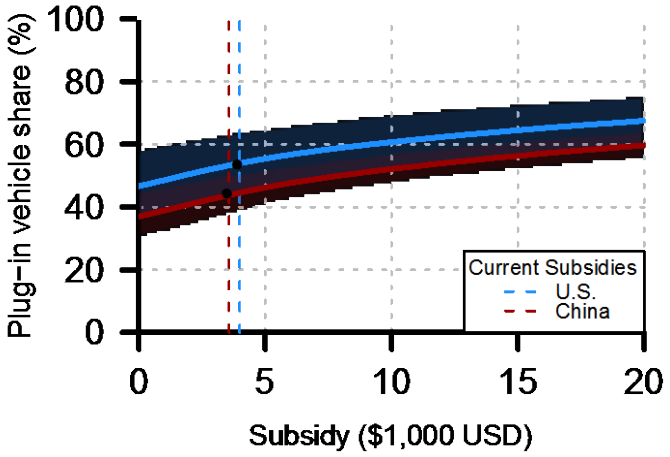
photos from motortrend.com

PHEVs attractive in both countries

PHEV-11 vs. HEV (Toyota Prius)

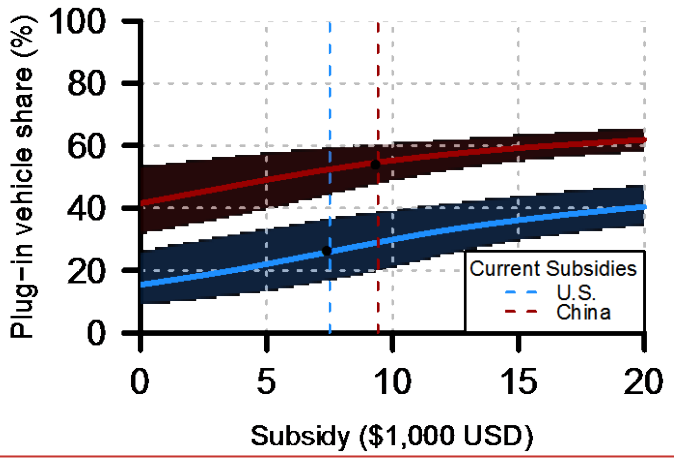


PHEV-21 vs. HEV (Ford C-Max)

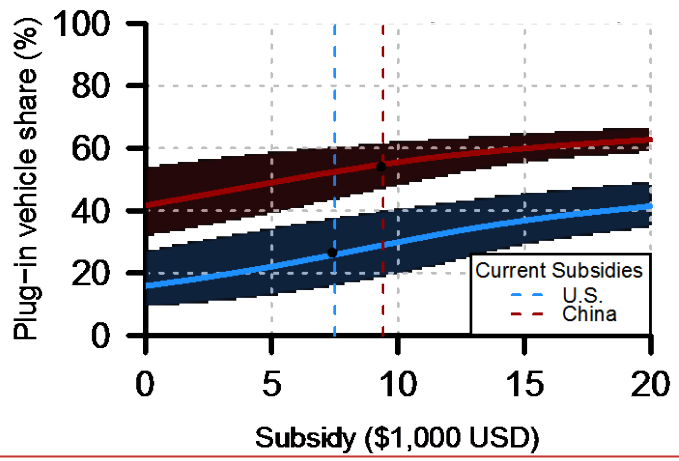


BEVs more attractive in China than U.S.

BEV-73 vs. CV (Nissan Leaf vs. Versa)



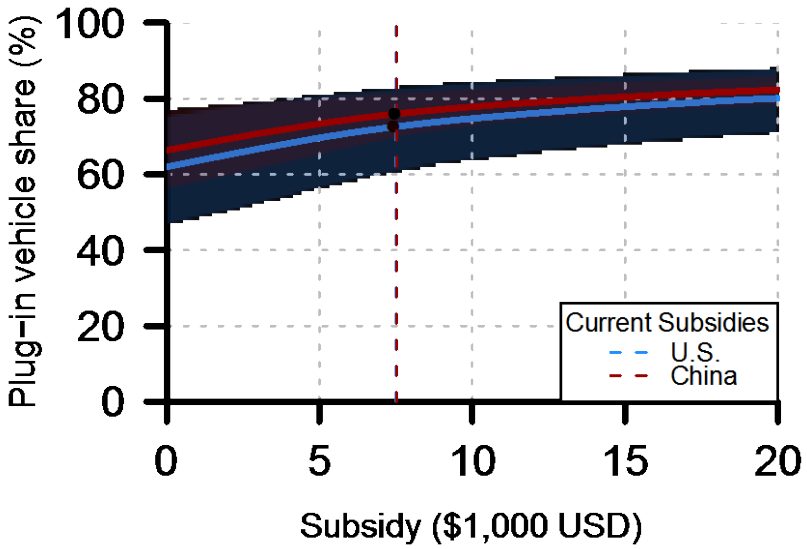
BEV-76 vs. CV (Ford Focus)



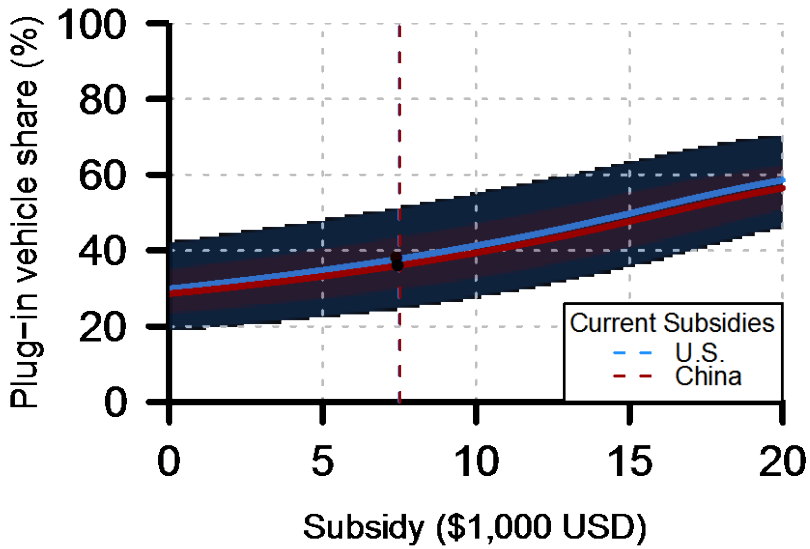
Technologies alone are not all that matters

photos from motortrend.com


PHEV-40 vs. CV (BYD F3)




PHEV-35 vs. CV (Chevy Volt vs. Cruze Eco)

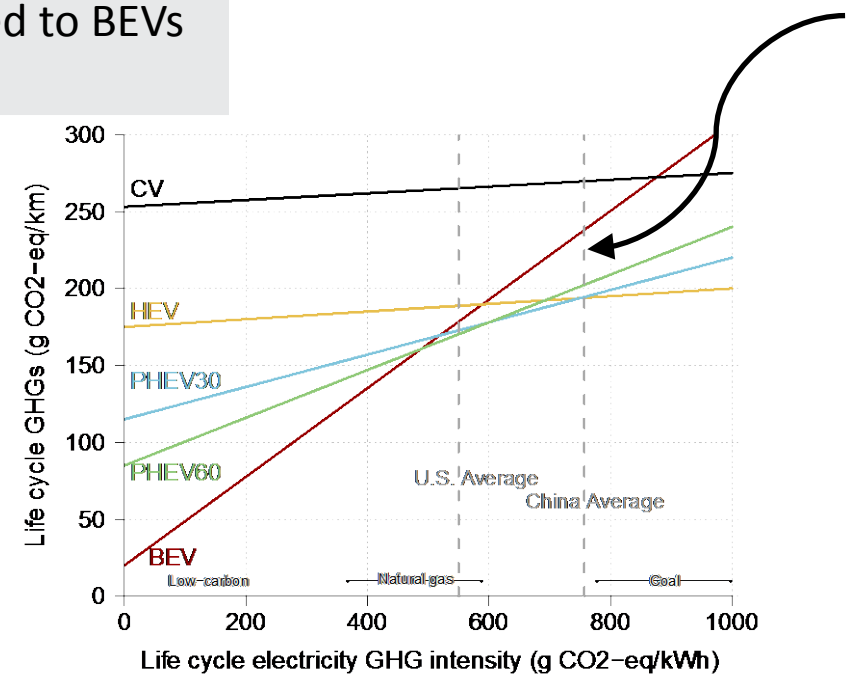


Vehicle	Price	Opcost (cents/mile)	0 – 60 mph Acceleration Time (sec)
BYD F3DM PHEV-40	$28,800	8	10.5
BYD F3 CV	$9,000	12	11.8

Vehicle	Price	Opcost (cents/mile)	0 – 60 mph Acceleration Time (sec)
Chevy Volt PHEV-35	$41,000	9.7	8.9
Chevy Cruze Eco CV	$20,120	11	8.8

Interaction of Preferences & Policy

	Preferences
U.S.:	• PHEVs neutral. • BEVs hard sell.
China:	• No strong preference towards PHEVs vs. BEVs. • Far less opposed to BEVs than U.S.



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