

Quantifying Plug-in Electric Vehicle Mileage and Resale Value

John Paul Helveston, George Washington University

Eliese Ottinger, George Washington University

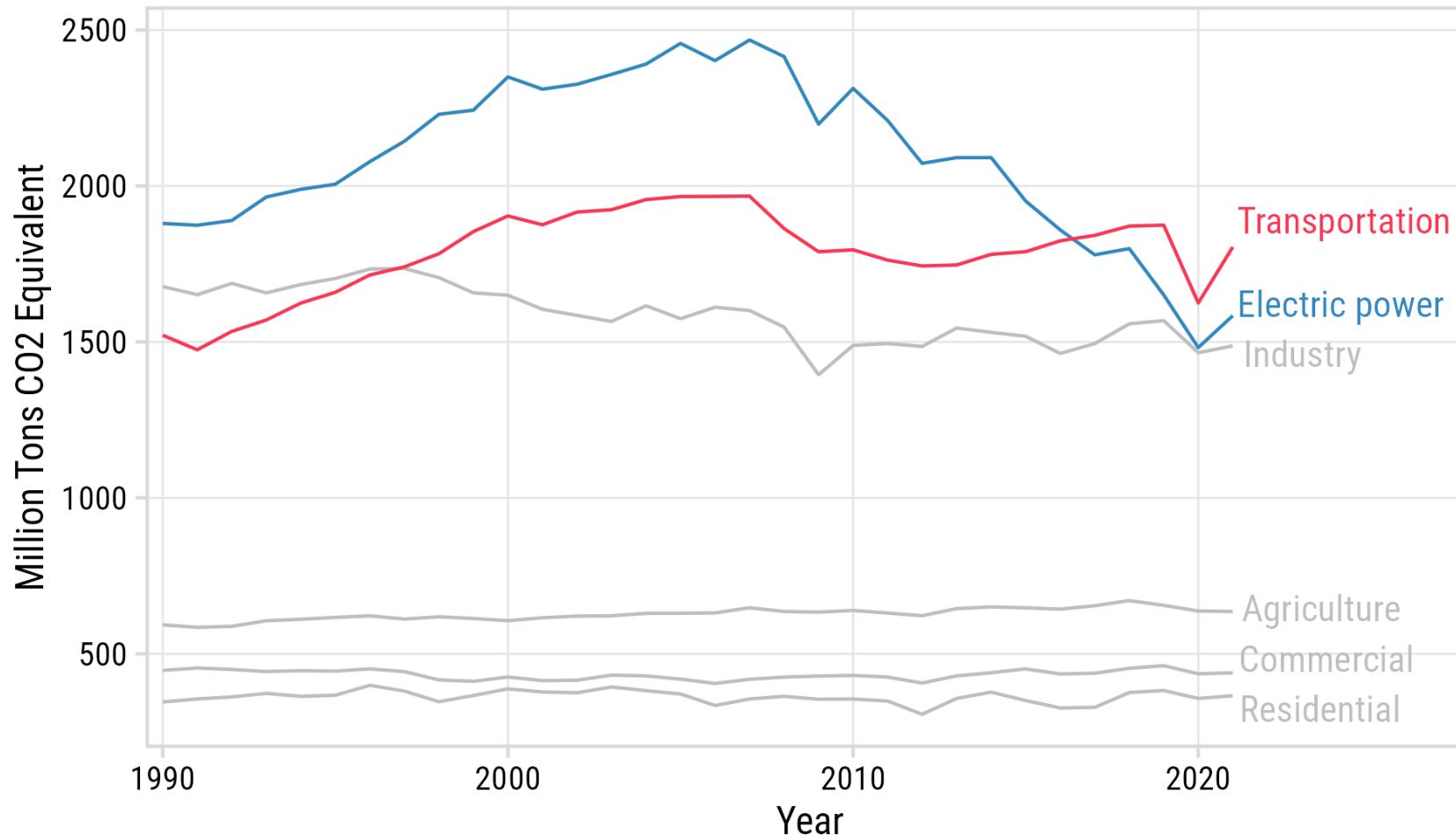
Lujin Zhao, George Washington University

Laura Roberson, George Washington University

June 1, 2023

Electrifying the passenger vehicle fleet is a critical climate goal

GHG Emissions by U.S. Sector



Two Studies, One Dataset

Measuring Electric Vehicle **Mileage** in the United States

Lujin Zhao (Ph.D. Student)
Eliese Ottinger (Undergraduate RA)

Status: Paper submitted for review soon

Measuring Electric Vehicle **Resale Value** in the United States

Laura Roberson (Ph.D. Student)

Status: Exploratory phase

Data: ~13M used vehicle listings from 60k dealerships (2016 - 2022)

	Conventional	Hybrid	PHEV	BEV (Non-Tesla)	BEV (Tesla)
# of Listings	12,604,702	610,946	130,889	118,580	57,193
Miles (1,000)					
mean	52	57	43	27	36
sd	32	35	26	15	21
Age (years)					
mean	4.5	4.7	4.1	4.2	4.2
sd	1.8	1.8	1.4	1.4	1.5
Price (\$USD)					
mean	15,928	15,448	19,263	14,658	50,181
sd	6,852	5,096	12,748	6,053	12,380
Electric Range (miles)					
mean		33	104	251	
sd		14	48	50	
min		11	58	139	
max		53	259	402	

Going the Distance: Quantifying Electric Vehicle Mileage in the United States

Lujin Zhao (Ph.D. Student)

Eliese Ottinger (Undergraduate RA)

John Paul Helveston, Ph.D.

The George Washington University

We really need to understand PEV usage

- PEV emissions reduction benefit **depends on vehicle usage**
[Jenn \(2020\)](#)
- Energy modelers typically assume **CV miles = BEV miles**
- Revenue from proposed mileage tax **depends on vehicle usage**
[Metcalf et al. \(2022\); Zhao and Mattauch \(2022\); Davis and Sallee \(2020\)](#)
- PEV adoption depends on **how well PEVs substitute for CVs**
[Xing et al. \(2021\)](#)

Conflicting prior results on BEV mileage

Study	Estimated Annual Mileage	Sample Location	Sample Size (BEVs [*])	Data Year(s)	Data Source
Burlig et al. (2021)	5,300	California	57,290	2019	Household electricity meter readings
Davis (2019)	6,300	US	436	2017	NHTS [†]
Jia and Chen (2022)	10,000	California	184	2019	2019 California Vehicle Survey
Tal et al. (2020)	12,500	California	100	2015 - 2018	On-board vehicle sensors
This Study (2023)	6,960	US	176,413	2016 - 2022	Used vehicle listings

*Sedans only

†National Household Travel Survey

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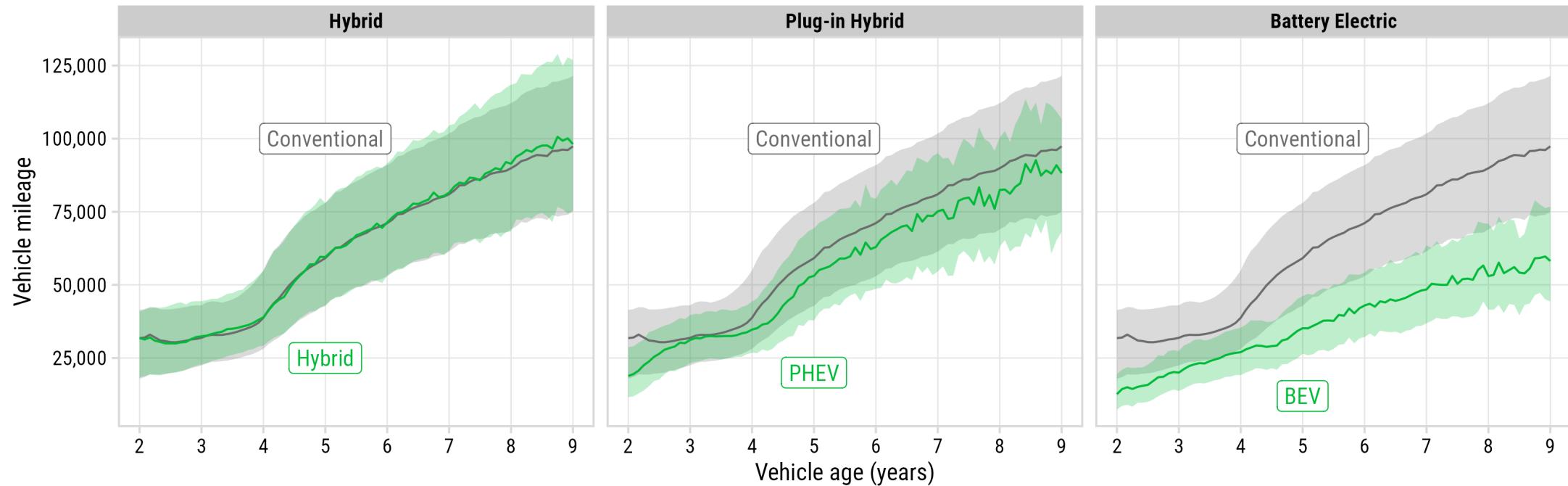
Inconsistent data quality in prior studies

Study	Estimated Annual Mileage	Sample Location	Sample Size (BEVs*)	Data Year(s)	Data Source	Large N	Nationally Representative	Direct VMT Measurement
Burlig et al. (2021)	5,300	California	57,290	2019	Household electricity meter readings	X		
Davis (2019)	6,300						X	
Jia and Chen (2022)	10,000	US	436	2017	NHTS†			
Tal et al. (2020)	12,500							X
This Study (2023)	6,960	US	176,413	2016 - 2022	Used vehicle listings	X	X	X

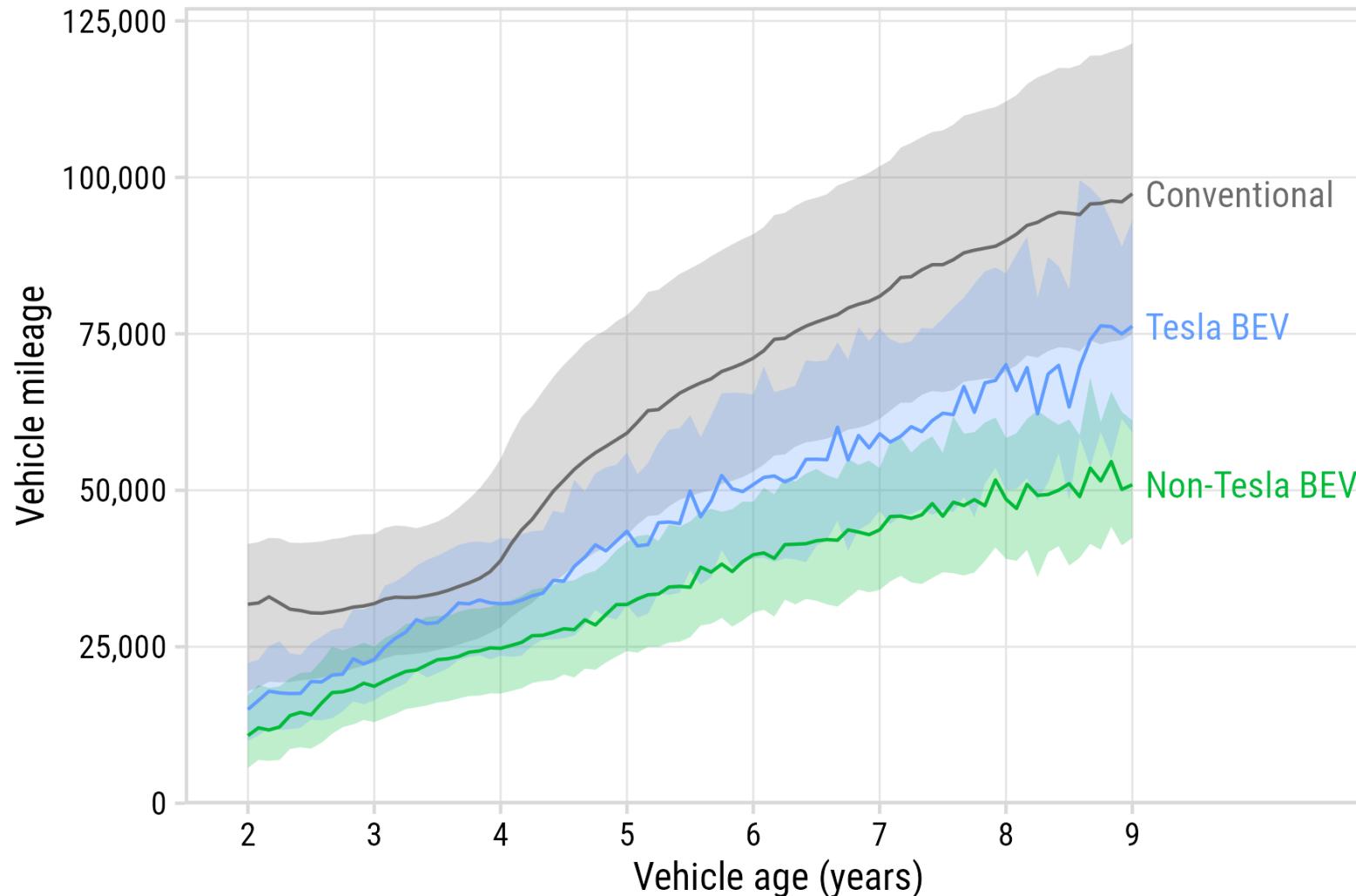
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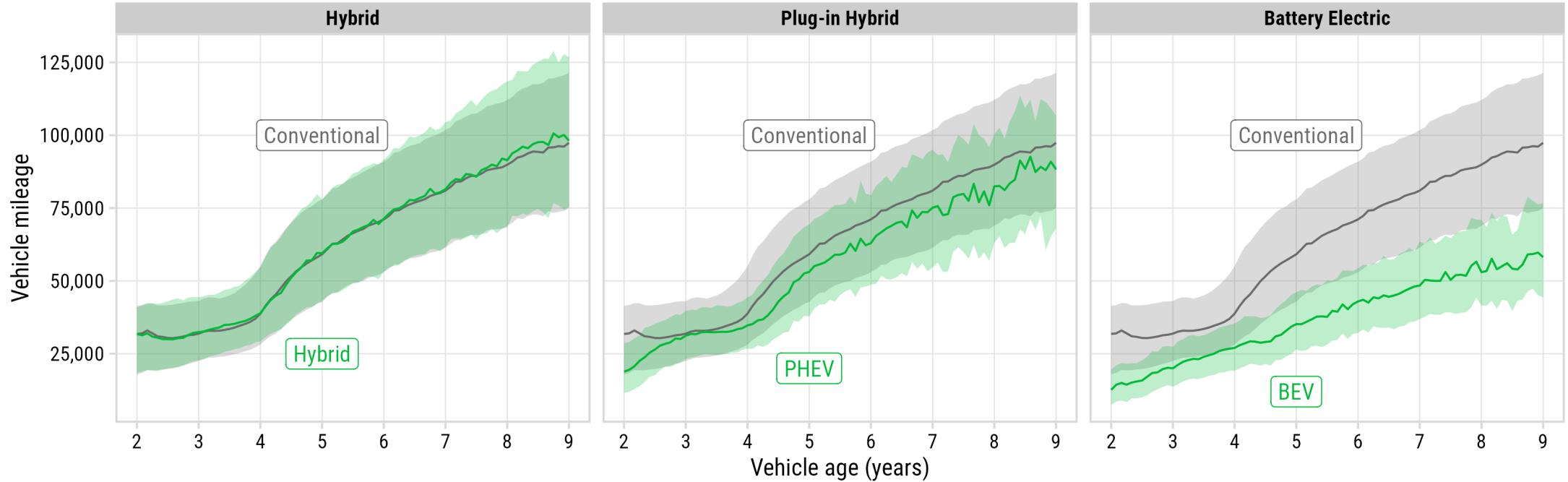
BEVs are driven significantly less than other powertrains



Teslas driven more than non-Tesla BEVs (but not as much as CVs)



BEVs are driven significantly less than other powertrains



$$mileage = \beta_0 + \beta_1 age + \beta_2 age * powertrain + \beta_3 age * cents_p_mile + \epsilon_i$$

	Model 1	Model 2	Model 3
(Intercept)	-9.981*** (0.041)	-9.981*** (0.041)	-15.841*** (0.099)
age_years	11.749*** (0.004)	11.749*** (0.004)	12.830*** (0.016)
age_years:powertrain_hybrid	0.439*** (0.018)	0.439*** (0.018)	-0.066** (0.021)
age_years:powertrain_phev	-0.728*** (0.047)	-0.728*** (0.047)	-1.213*** (0.047)
age_years:powertrain_bev	-4.790*** (0.042)	-5.605*** (0.051)	-6.269*** (0.051)
age_years:powertrain_bev_tesla		-2.985*** (0.076)	-3.607*** (0.074)
age_years:cents_per_mile			-0.101*** (0.002)
Fixed Effects			
vehicle_model	Yes	Yes	Yes
Num. obs.	13,522,310	13,522,310	12,927,779
R ² (full model)	0.451	0.451	0.434
Adj. R ² (full model)	0.451	0.451	0.434

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

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BEVs driven
4,700 miles
less than CVs
on average

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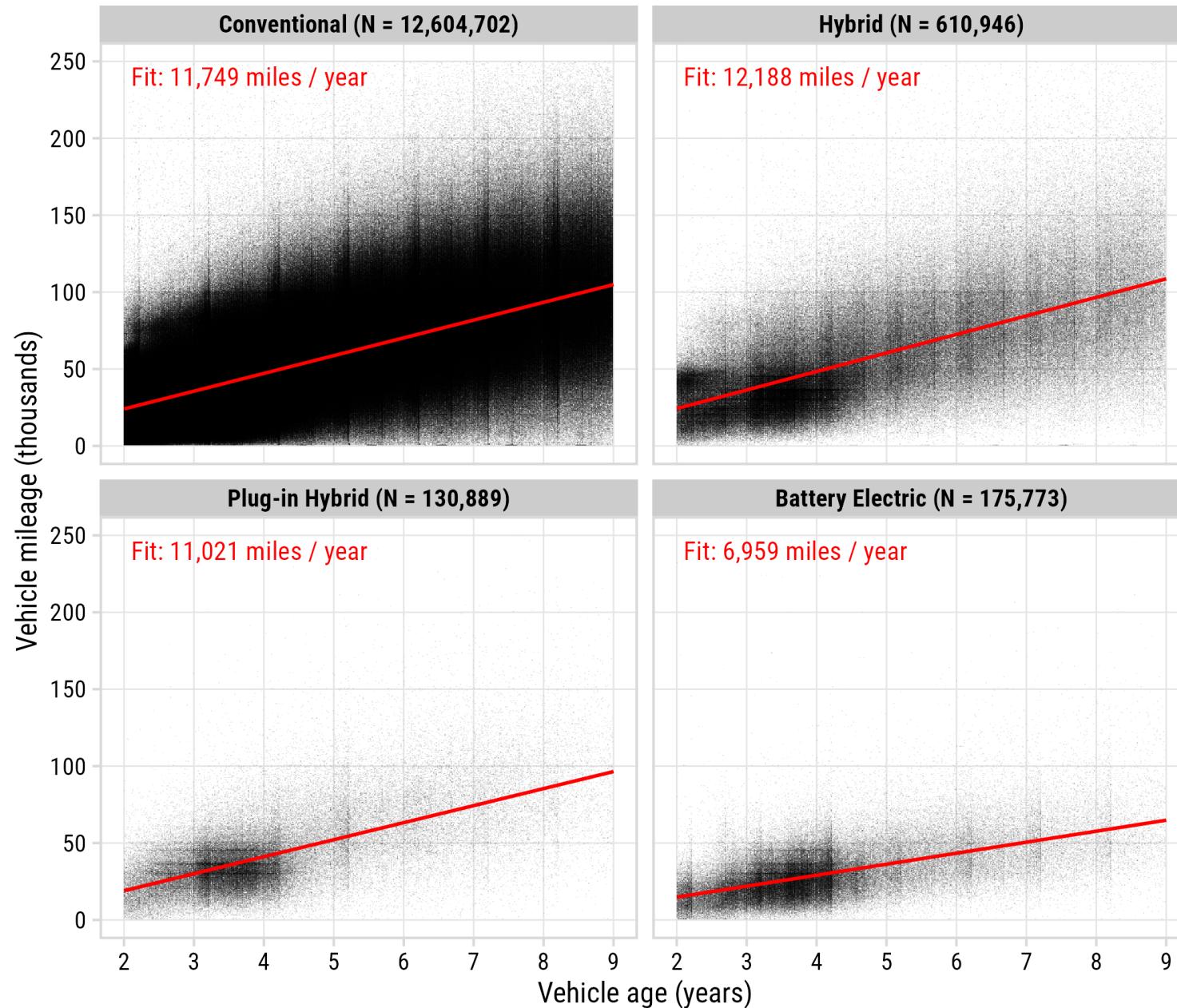
Non-Tesla
BEVs:
-5,600 miles

Tesla:
-3,000 miles

Fixed Effects

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***p < 0.001; **p < 0.01; *p < 0.05



BEVs:
~7k mi/yr

All others:
~11k - 12k mi/yr

Far less variability in
BEV mileage than CV
mileage

Powertrain:	BEV	Hybrid	PHEV	Conventional
(Intercept)	17.9692*** (2.3542)	-15.0761*** (1.4628)	-7.7242* (3.6598)	-34.4288*** (0.2646)
age_years	6.2250*** (0.1099)	14.3143*** (0.1276)	12.7519*** (0.2466)	13.7937*** (0.0165)
age_years:cents_per_mile	-0.0866*** (0.0201)	-0.3426*** (0.0199)	0.0458 (0.0352)	-0.2169*** (0.0016)
age_years:range_miles	0.0023*** (0.0007)		-0.0628*** (0.0034)	
age_years:modelfortwo	-2.0370*** (0.2292)			
age_years:modelspark	-0.0437 (0.1760)			
age_years:modelfocus	-0.3022* (0.1494)			
age_years:modeli3	0.8858*** (0.0752)			
age_years:modele-golf	-0.1080 (0.1609)			
age_years:model500e	-0.4605*** (0.1282)			
age_years:modelsoul	-0.2454 (0.2562)			
age_years:modelbolt ev	-4.1860*** (0.2016)			
age_years:modellmodel 3	2.6341*** (0.2026)			
age_years:modellmodel s	2.3207*** (0.1051)			
Fixed Effects				
vehicle_model	Yes	Yes	Yes	Yes
state	Yes	Yes	Yes	Yes
Num. obs.	175773	562747	130025	12059234
R ² (full model)	0.4098	0.3985	0.4488	0.4454
Adj. R ² (full model)	0.4096	0.3985	0.4486	0.4454

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Modest range effect:

+100 mi range =
+200 mi/yr

Tesla effect isn't just from range

BEV mileage less sensitive to operating cost than CV mileage

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1 cent increase in operating cost:

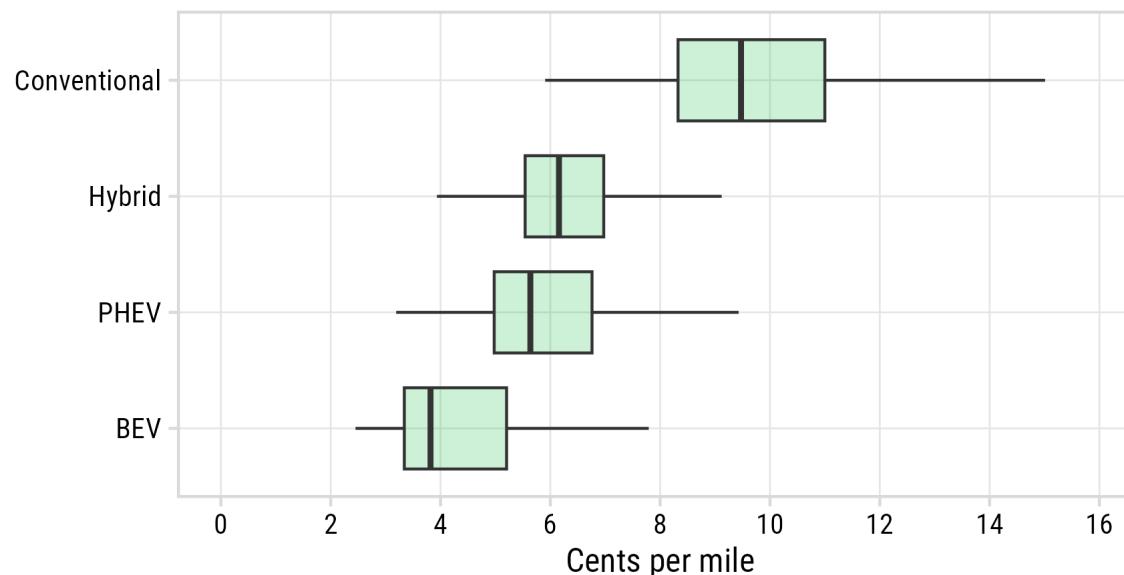
BEV: -87 mi/yr

CV: -217 mi/yr

HEV: -343 mi/yr

BEV mileage less sensitive to operating cost than CV mileage

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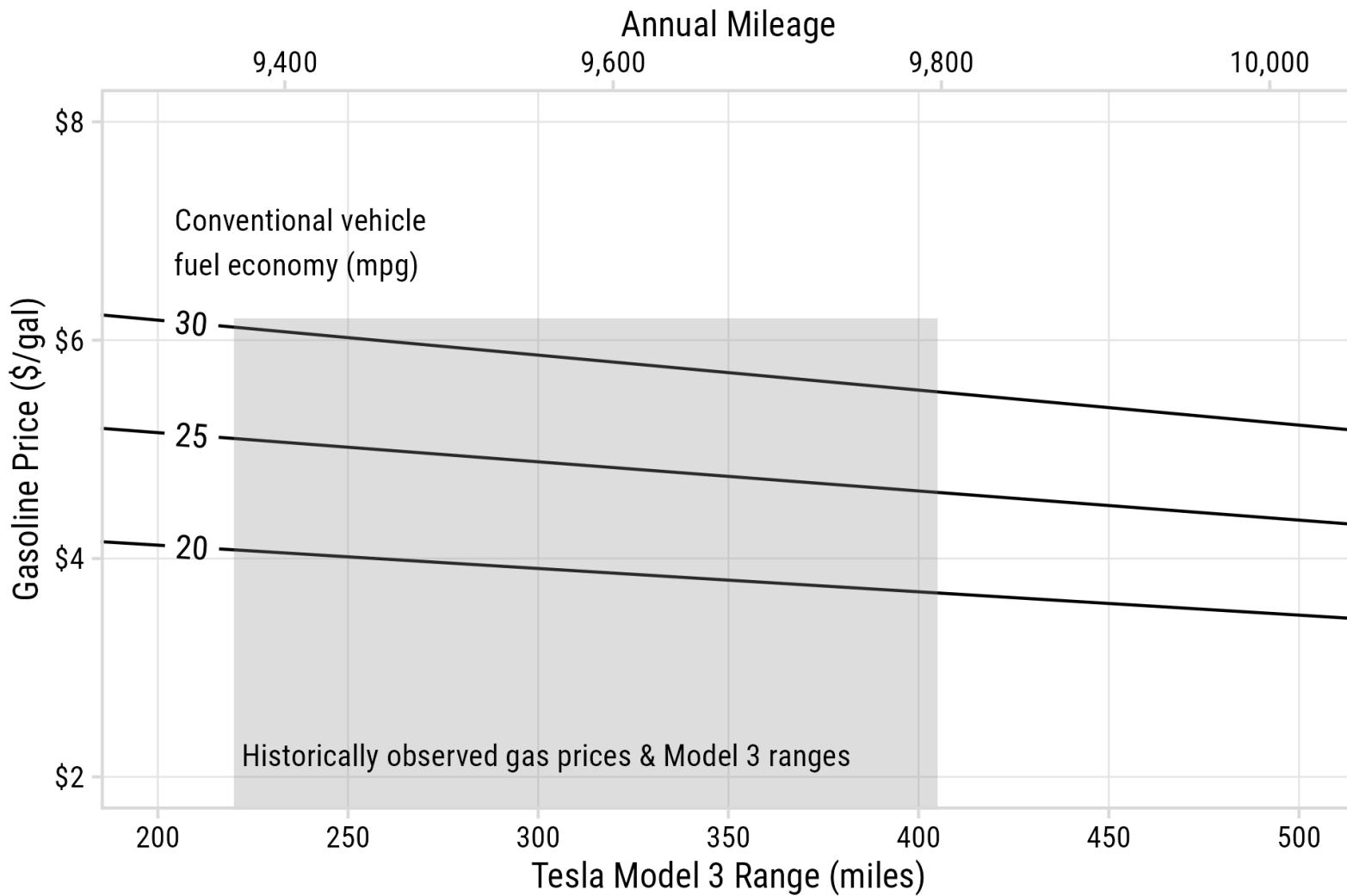
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CV: -217 mi/yr

HEV: -343 mi/yr

(BEVs have much lower operating costs)

Gas needs to be \$4-6/gal for equal mileage between CV & Tesla Model 3



Key takeaways

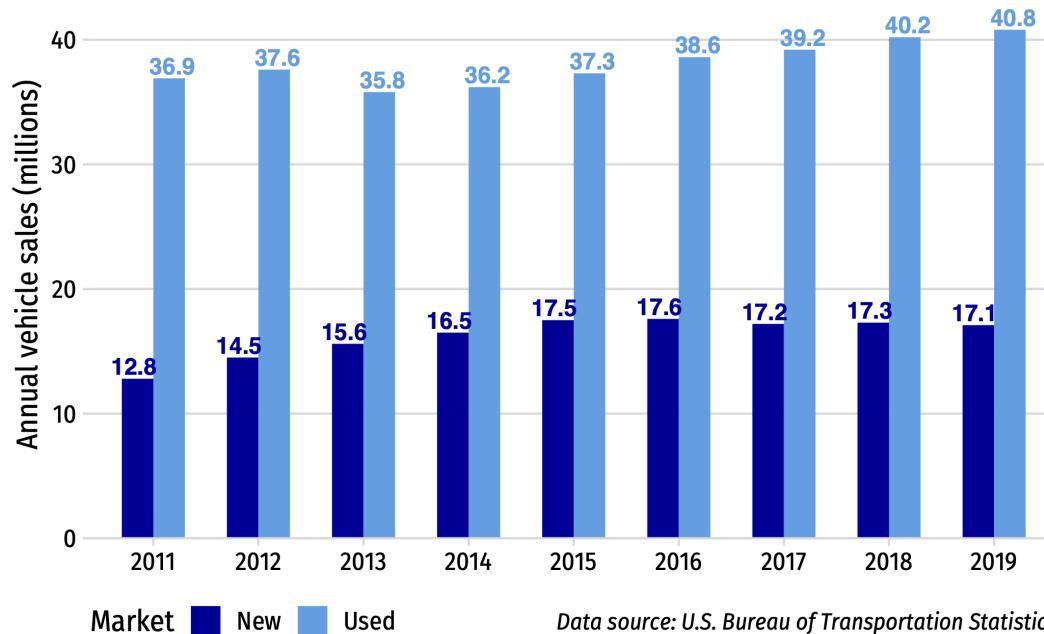
- BEVs are driven significantly less than other powertrains:
Non-Tesla BEVs: -5,600 miles; Tesla: -3,000 miles
- Far less variability in BEV mileage than CV mileage
(BEVs only substituting for lower-mileage CV usage)
- BEV mileage less sensitive to operating cost than CV mileage
- Even for Teslas, equal mileage with CVs requires higher gas prices

Battery-Powered Bargains? Measuring Electric Vehicle Resale Value in the United States

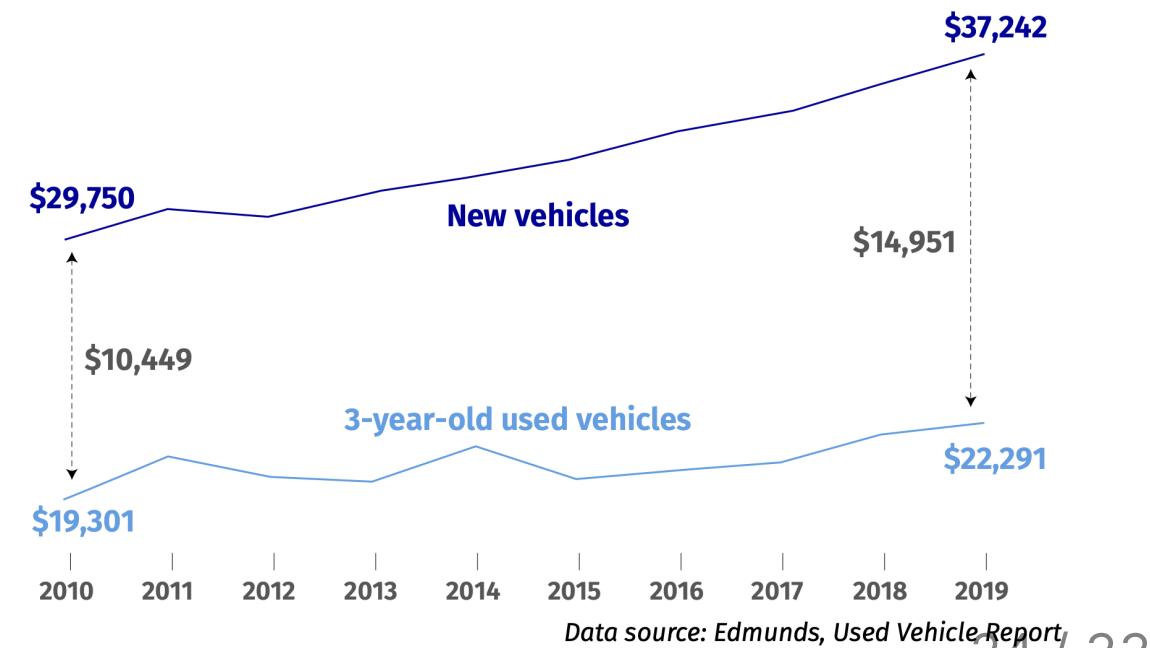
Laura Roberson (Ph.D. Student)
John Paul Helveston, Ph.D.

The vehicle resale market is critically important

70% of sales are used vehicles



Used vehicles are more affordable (pre-covid)

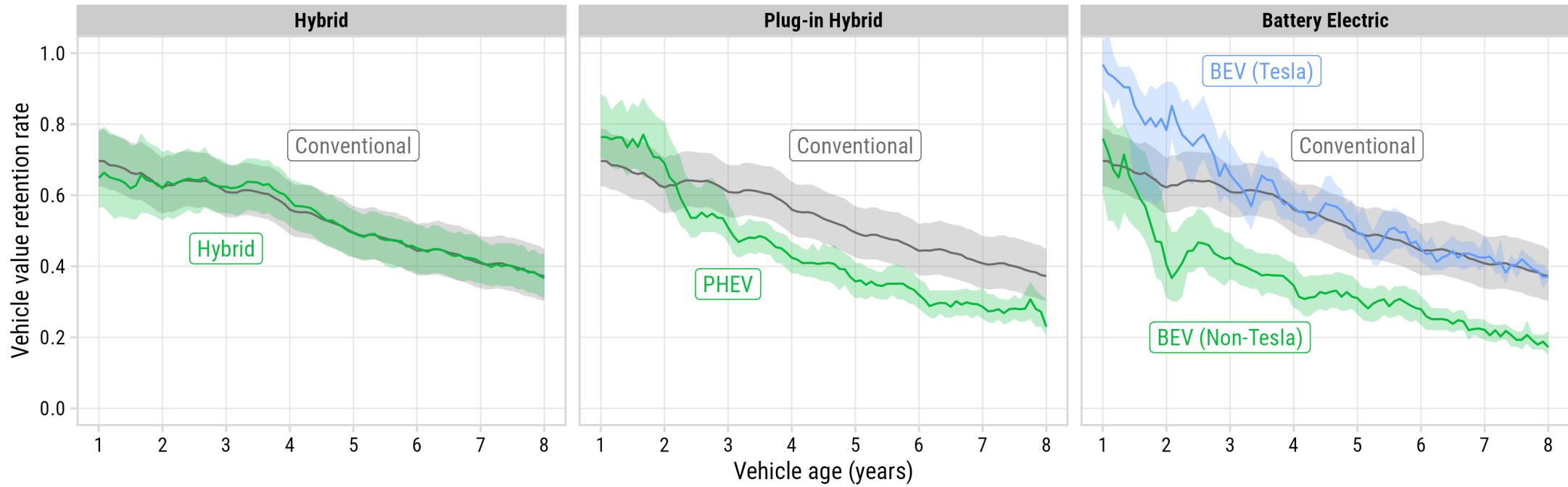


We really need to understand PEV resale value

- Depreciation is a key component in "Total Cost of Ownership" (TCO) models, e.g. [ANL's TCO Study](#)
- "Resale anxiety" a potential obstacle to electric vehicle adoption
[Brückmann et al. \(2021\)](#)
- BEV buyers nervous about depreciation tend to lease rather than buy
[Dua et al. \(2019\)](#)

BEVs & PHEVs are depreciating worse than CVs and HEVs

(Except Tesla)



Data: All listings between 2016 - 2019 (inclusive)

PEV subsidies for new cars (should) impact used car pricing

New Market

(MSRP - Subsidy = Price)
\$30,000 - \$7,500 = **\$22,500**

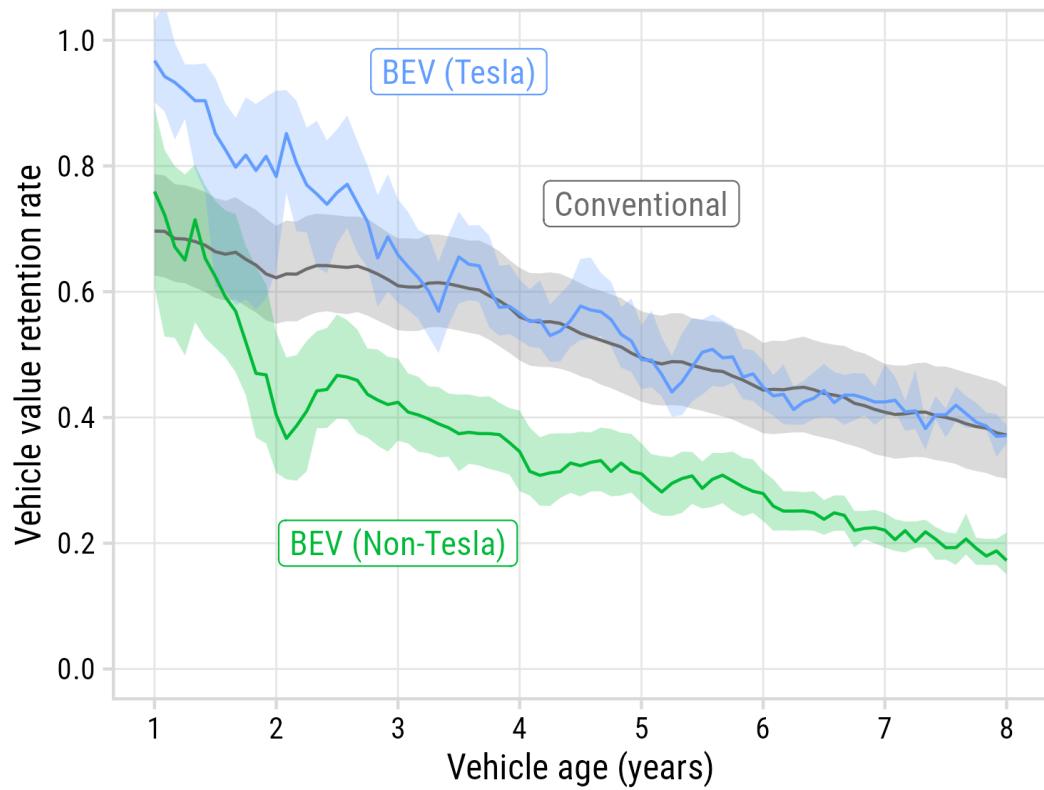


Used Market

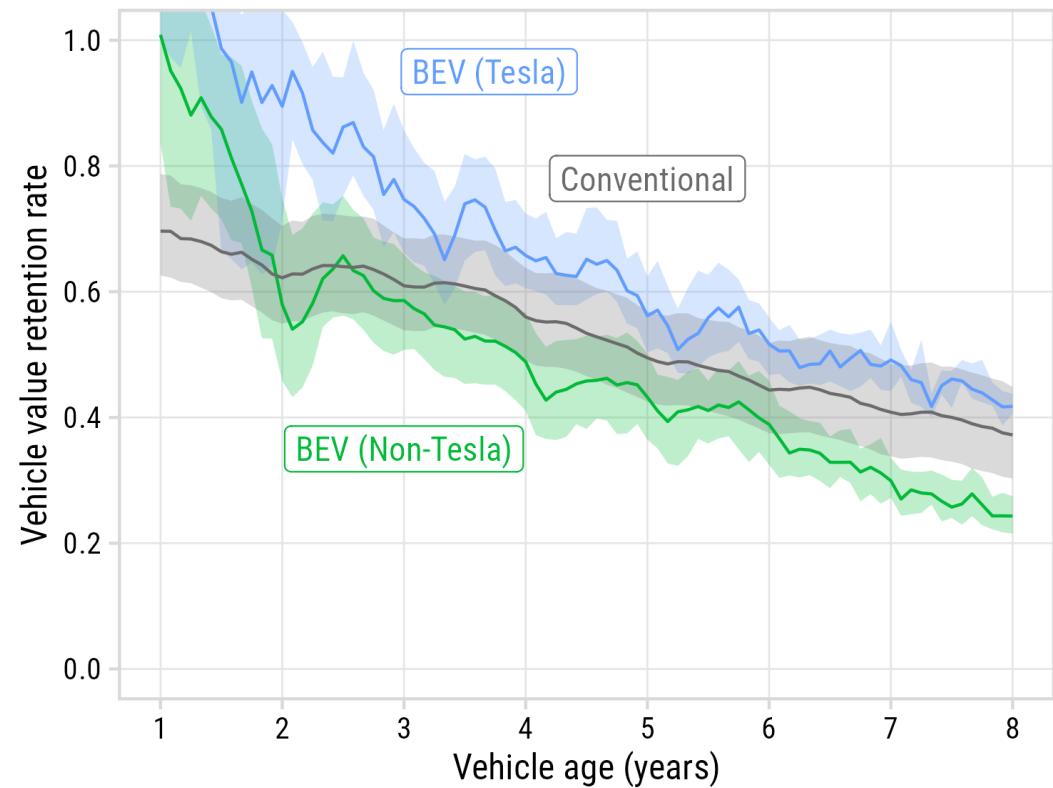
(Assuming adequate supply)
Max Price = **\$22,500**



$\frac{Price}{MSRP}$



$\frac{Price}{MSRP - Subsidy}$



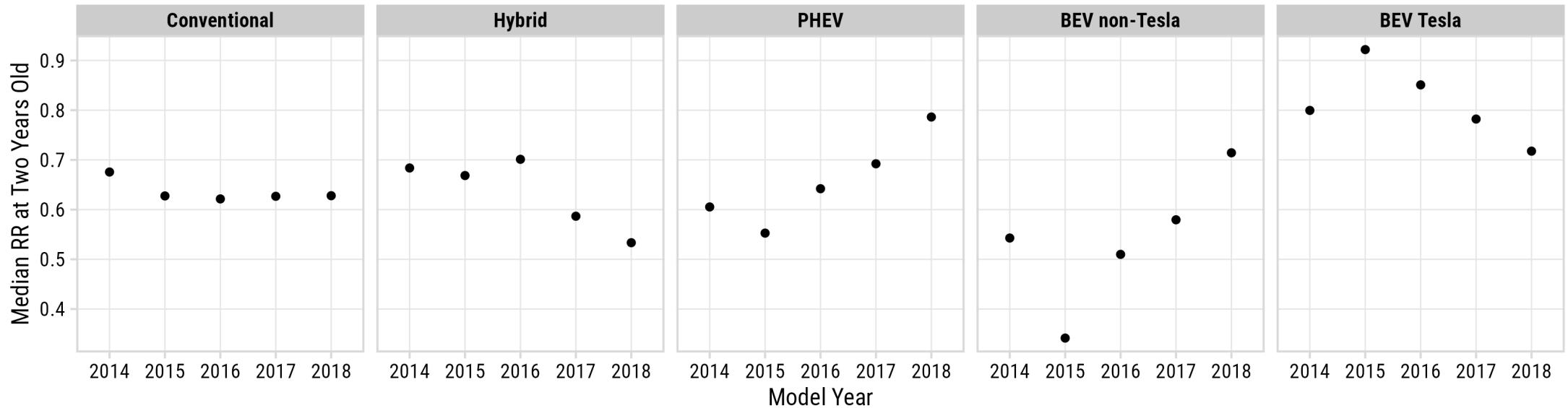
(Super preliminary modeling results)

	Conventional	Hybrid	PHEV	BEV (Non-Tesla)	BEV (Tesla)
(Intercept)	0.9965*** (0.0006)	0.9962*** (0.0018)	0.4553*** (0.0121)	-0.7675*** (0.0231)	0.5048*** (0.0290)
log(age_years)	-0.0714*** (0.0001)	-0.1134*** (0.0004)	-0.2270*** (0.0019)	-0.1565*** (0.0018)	-0.1543*** (0.0035)
log(miles)	-0.0898*** (0.0001)	-0.0915*** (0.0003)	-0.0779*** (0.0008)	-0.0531*** (0.0007)	-0.0692*** (0.0016)
log(cents_per_mile)	-0.0243*** (0.0003)	0.0536*** (0.0008)	0.1668*** (0.0025)	0.0013 (0.0017)	-0.0278*** (0.0049)
log(range)			0.2296*** (0.0041)	0.3696*** (0.0049)	0.1228*** (0.0047)
Num. obs.	9,189,853	490,932	58,915	74,331	22,518
R ² (full model)	0.4420	0.5875	0.7706	0.5738	0.4952
Adj. R ² (full model)	0.4420	0.5875	0.7706	0.5738	0.4951

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$

$$rr = \beta_0 + \beta_1 \log(age) + \beta_2 \log(miles) + \beta_3 \log(cents_p_mile) + \beta_4 \log(range) + \epsilon_i$$

Some (tentative) evidence that newer PEVs are depreciating less than older PEVs



Questions we hope to answer with this study

Are PEVs depreciating faster than CVs?

Which PEV features matter for retaining value?

Is this changing over time?

What is the impact of new car subsidies on pricing in the used market?

Thanks!

Slides:

<https://slides.jhelvy.com/2023-isa-conf/>

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Extra slides