The Effects of “Buy American”: Electric Vehicles and the Inflation Reduction Act

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Motivation

Inflation Reduction Act

- ‘Most ambitious climate investment in world history’ (White House 2023)
  - Goals: climate mitigation, green jobs, industrial policy, ...
  - Uniform subsidies, domestic clean technology
  - “Bottomless mimosas brunch special” (Yablon 2023)
- Electric vehicle tax credits: $70 to $390 billion cost? (Bistline, Mehrotra, & Wolfram 2023)
- Cloudy future: “terribly harmful to the economy” (House Speaker Mike Johnson)

Research questions:

- IRA EV credits’ efficiency, distributional effects?
- Gains from differentiating EV policies across vehicles?
- Green industrial policy: trade v. environment? foreign v. domestic welfare?
  - Emmanuel Macron (2022, 2023): “super aggressive,” “common objective”

Motivation

Many of the US's allies like Japan, Canada, and especially the European Union have not been all-in. They see the Biden administration's signature accomplishments – such as the Inflation Reduction Act (IRA) – less as long-awaited efforts to finally make good on promises of climate action and more as a threat to the ability of places like Europe to attract investment themselves. . . .

After decades of pleading with America to finally take action on issues such as climate, why are our closest partners so annoyed at us now that we're actually doing what they asked?
– *(Yablon 2023)*

Results

1. Descriptive patterns

- At global social cost of carbon, EVs have lower mean externalities
- Similar externality dispersion within EVs as within gas vehicles

2. Event study analyses

- Short-run incidence on consumers
- Trade restrictions drive shift to leasing

3. Equilibrium supply-demand model (counterfactual: pre-IRA policy)

- Benefits per dollar of costs (MVPF):
  - $1.87 compared to pre-IRA policy
  - $1.02 compared to no EV credits
- $23,000 to $32,000 per additional EV (66% to 75% inframarginal)
- Trade versus environment
- Leasing loophole does poorly
- Differentiating subsidies across models doubles benefits

Approach and data

Comprehensive data

- Propietary: Cox, Experian, Edmunds, Strategic Vision
- Administrative: CA, TX registration microdata; Treasury credit eligibility; EPA exhaust tests
- Original: Tesla web scraping, survey of 250 dealerships

What is new here

- **Clean vehicle tax credits**:
  - Ex post empirical microeconomic welfare analysis of central part of IRA
  - Overviews (Bown 2023; Buckberg 2023)
  - Evaluations of past credits (Chandra et al. 2010; Sallee 2011; Gallagher & Muehlegger 2011; Jenn, Azevedo & Ferreira 2013; Jenn, Springel & Gopal 2018; Clinton & Steinberg 2019; Sheldon & Dua 2019; Xing et al. 2021; Muehlegger & Rapson 2022; Lohawala 2023)
  - Ex-ante evaluations of IRA credits (Cole et al. 2023; Slowik et al. 2023; Bistline, Mehrotra, & Wolfram 2024; Hahn et al. 2024)
  - Long-run benefits (Linn 2022; Barwick et al. 2023, 2024; Head et al. 2024)
- **Trade and the environment**
- **Auto market environmental regulation**

What is new here

- **Clean vehicle tax credits**

- **Trade and the environment:**
  - Theoretical+empirical analysis of profit shifting and the environment
  - Overviews (Copeland & Taylor 2003; Cherniwchan, Copeland & Taylor 2017; Copeland, Shapiro & Taylor 2022; Balboni & Shapiro 2024; Desmet & Rossi-Hansberg 2024)
  - Profit shifting (Brander & Spencer 1981, 1984; Venables 1985; Bagwell & Staiger 2012)
  - Trade+environment, issue linkage (Rodrik 2014; Nordhaus 2015; Maggi 2016; Costinot, Donaldson, & Smith 2016; Larch & Wanner 2017; Shapiro & Walker 2018; Shapiro 2021; Kortum & Weisbach 2021; Levaggi & Panteghini 2023; Caliendo et al. 2024; Farrokhi & Lashkaripour 2024)
  - Concentrated dirty industries (Buchanan 1969; Fowlie, Reguant, & Ryan 2016; Ganapati, Shapiro, & Walker 2020; Hsiao 2024)
  - NTBs (Conconi et al. 2018; Head, Mayer, & Melitz 2022; Cox & Acosta 2023; Bombardini et al. 2024)

- **Auto market environmental regulation**

What is new here

- **Clean vehicle tax credits**

- **Trade and the environment**

- **Auto market environmental regulation:**
  - Heterogeneous EV externalities: market power, profit shifting, fiscal externality, fatal accidents
  - Empirical frameworks (Goldberg 1998; Bento et al. 2009; Fowlie et al. 2012; Jacobsen 2013; Knittel & Sandler 2018; Jacobsen & van Benthem 2015; Gillingham et al. 2021; Jacobsen et al. 2022, 2023)
  - Heterogeneous externalities theory (Diamond 1973)
  - EV externalities (Holland et al. 2016; 2019; 2020)

Important caveats

- **Short to medium run. Important timeframe**:
  - Ex post analysis
  - Political budgeting, elections (!)
  - Rapid EV developments
  - Firm investment timeframes
  - Future work: learning by doing, supply chain adjustments, new models, retaliation from trade partners

- **Results follow externality assumptions**

Agenda

1. **Background**
2. Data
3. Descriptive facts
4. Event studies
5. Equilibrium model
6. Counterfactuals
7. Conclusions

Background: clean vehicle credits

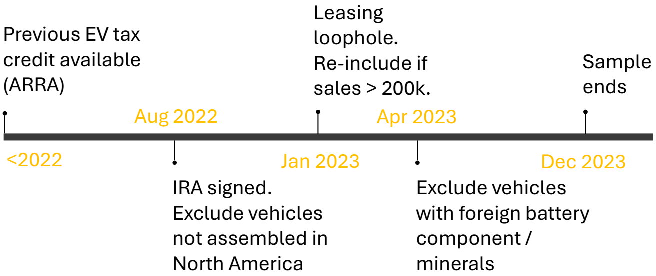
Internal Revenue Service code section 30D (2008)

- $7,500 tax credits for new EVs
- Eligibility: 200k per manufacturer
  - Ineligible: Tesla & GM (2018-9), Toyota & Ford (2022), Stellantis & BMW (2023)

Inflation Reduction Act (August 2022)

- 30D amendments
  - Jan 2023: income limits (~ 2/3 of EV buyers income eligible)
  - Trade restrictions
- 45W: commercial credit
  - Jan 2023: leases qualify
  - “Leasing loophole”: remove restrictions for income, price, trade

30D credit eligibility over time



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Data

- **General notes**
  - Submodel $\times$ month panel: Jan 2022 to Dec 2023
  - "Submodel" $\equiv$ make $\times$ model $\times$ trim $\times$ powertrain

- **Registration counts** (Experian) per submodel k, month t

$$\text{Lease share}_{kt} = \frac{\text{Leases}_{kt}}{\text{Registrations}_{kt}}$$

Data

- **Prices** (Cox, CA, Tesla)
  - Cox: dealership transaction microdata (31% of US, excludes Tesla/Rivian/Lucid)
    Includes dealership rebates, lease terms

$$\text{Lease price}_{kt} \equiv \text{PDV of lease payments}_{kt} + \text{Residual value}_{kt}$$
$$\text{Relative lease price}_{kt} \equiv \text{Lease price}_{kt} - \text{Purchase price}_{kt}$$

  - California DMV registration microdata (32% of US EVs)
    (k, t) correlation with Cox prices: 0.99
  - Tesla prices, lease terms (Tesla website)

- **Second choice survey data** (National Vehicle Experience Survey)

Data: Summary statistics

	Mean	Std. dev.	Min.	Max.	Obs.
Registrations	1,079	1,887	26	38,781	19,019
Purchase price ($000s)	51.3	19.3	12.7	96.7	17,691
Lease price ($000s)	48.1	20.9	16.3	372.3	15,746
Percent leased	25.1	17.8	0	100	19,019

Data: Lifetime externality by submodel

- **General parameters**
  - Lifetime miles: 150,000 (EPA 2014)
  - Global social cost of carbon: $241 (EPA 2023)
    - ⋆ US SCC: $28/ton (Ricke et al. 2018)

- **Externalities**
  - Manufacturing and scrap
    - ⋆ CO_2 by powertrain (Argonne Natl Labs / GREET / Kelly et al. 2022)
  - Driving
    - ⋆ CO_2, local air pollution: follow Holland et al. (2016), update SCC, exhaust tests (EPA 2024)
    - ⋆ Electricity: short-run marginal emissions steady in 2010–2019 (Holland et al. 2022)
  - Fatal accidents (weight)
    - ⋆ Follow Anderson & Auffhammer (2014), $13.2 million VSL (Department of Transportation 2024)
  - Positive fiscal externalities
    - ⋆ Mean electricity markup: 12 ¢/kWh (Borenstein & Bushnell 2022) 64 ¢/gallon gas tax
  - Assume outside good externalities = GV externalities

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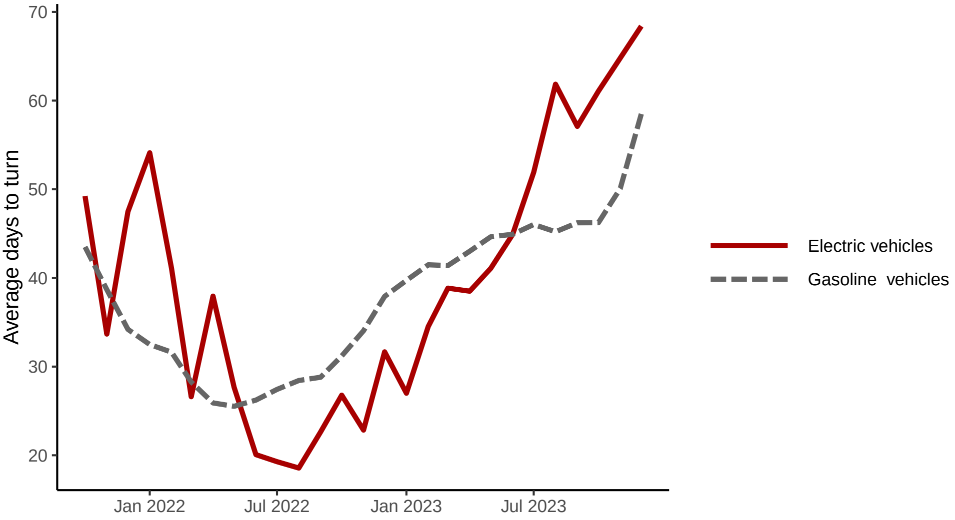
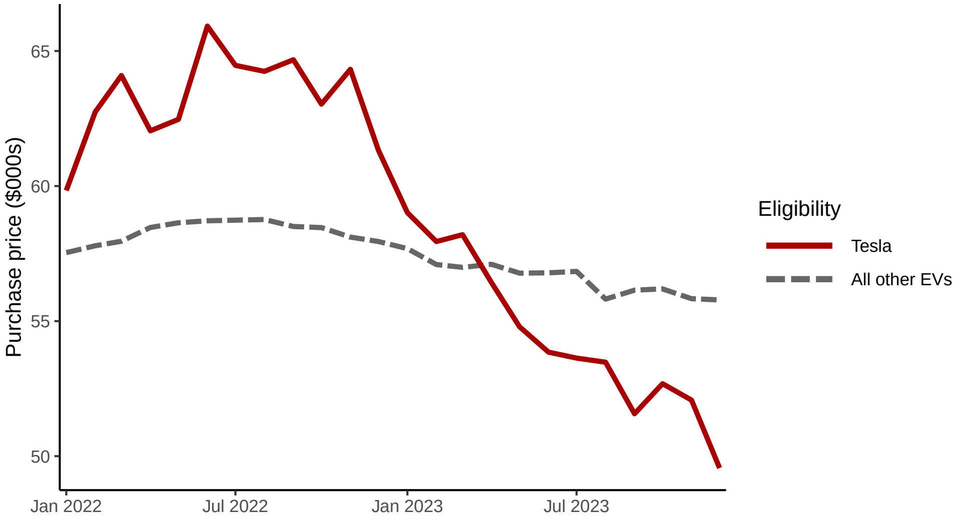
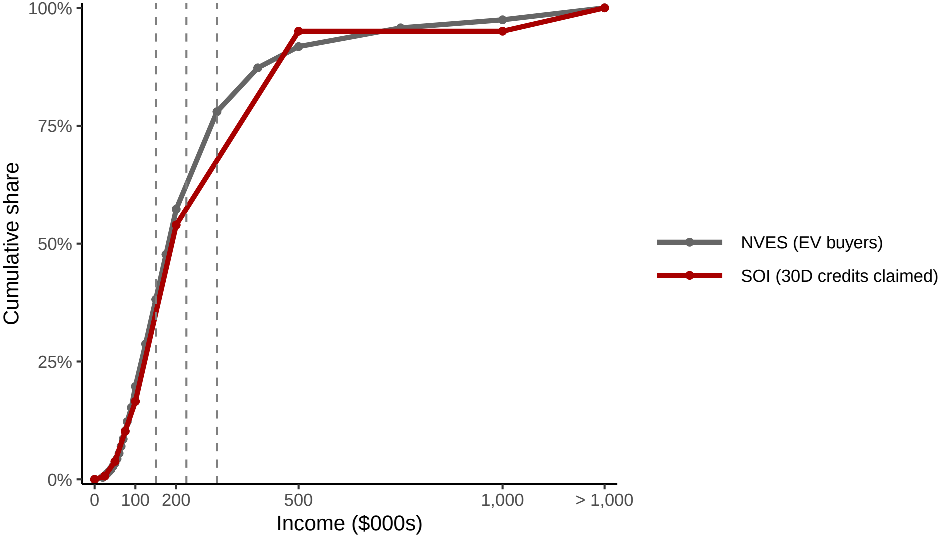
1. Tight inventory in mid-2022, surplus in 2023



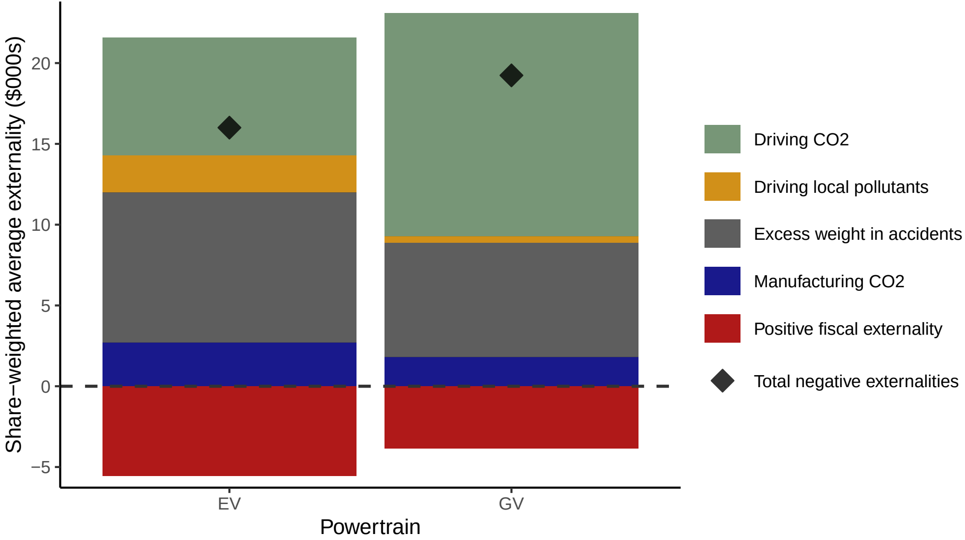
2. EV prices peaked in mid-2022



3. EV buyer incomes mostly below IRA limits



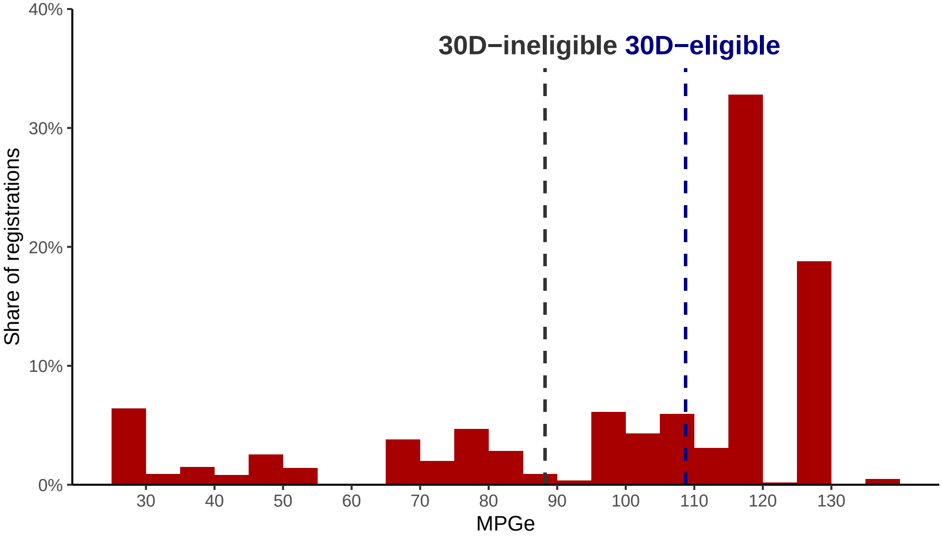
4a. Neg externalities: lower for EVs than gas vehicles at global SCC



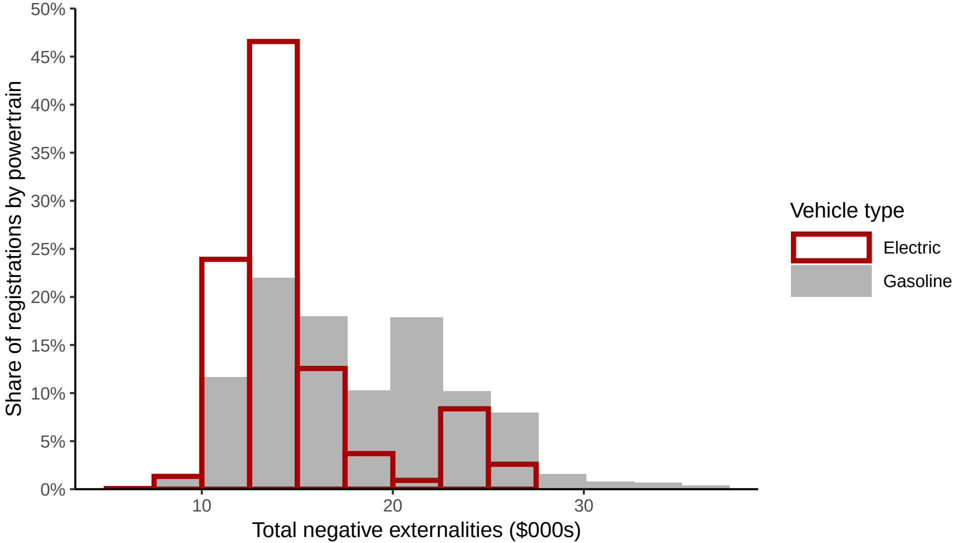
4b. Neg externalities: higher for EVs than gas vehicles at US SCC

	(1) All EVs	(2) Gasoline vehicles
Manufacturing CO_2 (global SCC)	\$2,719	\$1,813
Driving CO_2 (global SCC)	\$7,273	\$13,833
Driving local pollutants	\$2,294	\$378
Excess weight in accidents	\$9,277	\$7,068
Positive fiscal externality	\$5,560	\$3,854
Total negative externality		
Global SCC	\$16,003	\$19,239
Domestic SCC	\$7,162	\$5,393

5. Neg externalities: greater for foreign EVs



6a. Neg externalities: similar dispersion within EVs and within gas vehicles



6b. Neg externalities: dispersion example

Prius: $9,800 negative externality

Rivian R1S: $27,500 negative externality

6c. Neg externalities: dispersion statistics

	Standard deviation ($000s)		Coefficient of variation		Interdecile ratio	
	EVs	GVs	EVs	GVs	EVs	GVs
Panel (a): Global SCC						
Total negative externalities	4.24	5.05	0.25	0.25	1.08	1.07
	[0.031]		[0.947]		[−0.02, 0.01]	
Panel (b): Domestic SCC						
Total negative externalities	2.92	2.98	0.39	0.50	1.11	1.17
	[0.830]		[0.014]		[−0.09, −0.03]	

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4. **Event studies**
   - **Overview & purchase prices**
   - Relative lease prices
   - Purchase-lease substitution
5. Equilibrium model
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Event studies

Questions:

- Consumer v. producer incidence?
- Purchases-lease substitution?

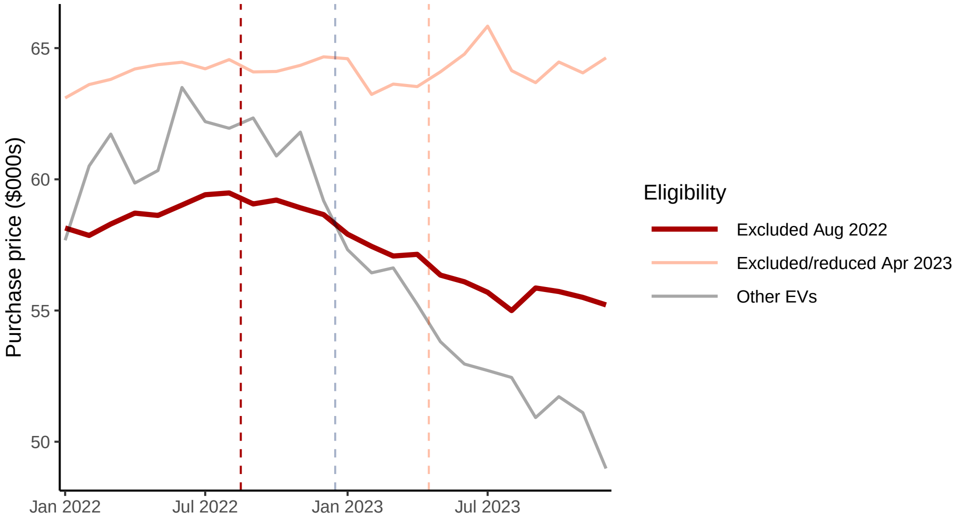
Approach: event study around eligibility changes

- Control group: gasoline vehicles
  - All vehicles affected in market equilibrium $\implies$ estimate relative effects
- Weight submodels by mean monthly registrations
- Cluster standard errors by model

Setup:

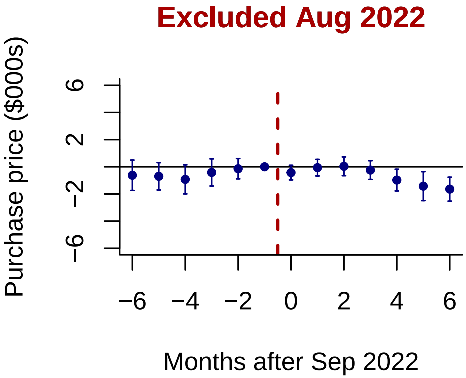
- Buyers claim subsidies on personal income taxes
- If credits don't change purchase prices $\implies$ incidence on consumers
- Context: inventory constrained in 2022, flexible in 2023

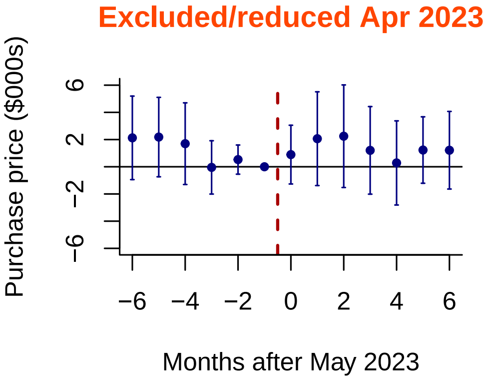
Trends: purchase prices



Event studies: purchase prices

$$y_{kt} = \sum_e \sum_{s \in \mathcal{S}^e} \gamma_s^e C_k \cdot 1\{t - s = t^e\} + \phi_k + \nu_t + \varepsilon_{kt}$$





- Periods -3 to +3, pooled: reject price decreases more than $620
- $\Longrightarrow$ Short-run incidence for purchase credits is on consumers

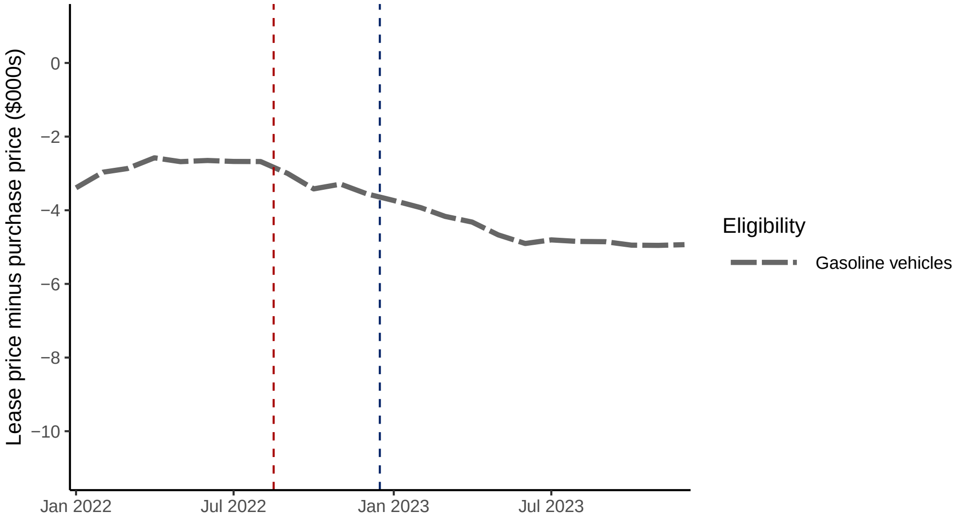
Agenda

Economic incidence: relative lease prices

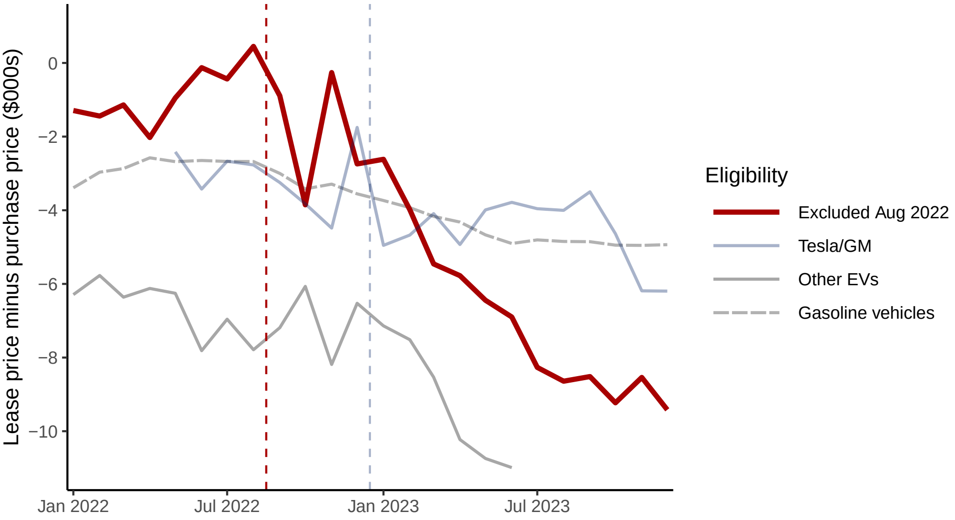
Setup:

- January 2023: 45W credits for leasing
- Test for changes in *relative lease price* (≡lease price – purchase price)

Relative lease prices: drop for gas vehicles as market softens

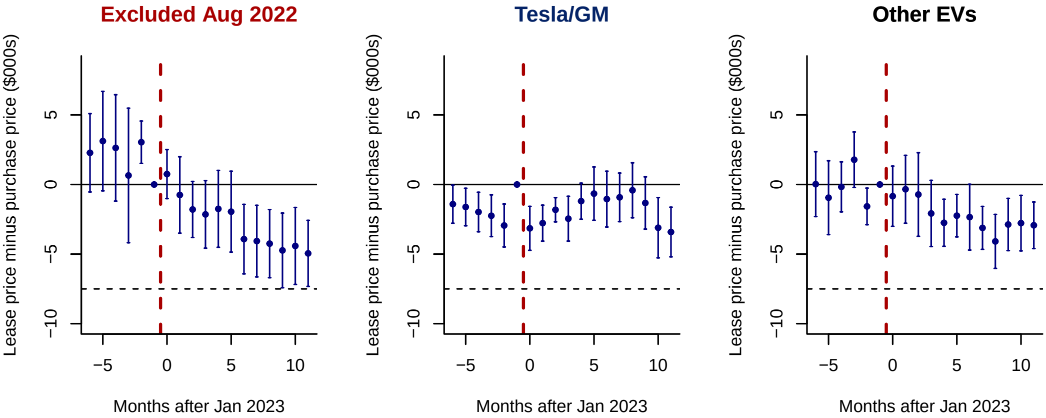


Trends: relative lease prices



Event studies: relative lease prices

$$y_{kt} = \sum_e \sum_{s \in \mathcal{S}^e} \gamma_s^e C_k \cdot 1\{t - s = t^e\} + \phi_k + \nu_t + \varepsilon_{kt}$$



- Aug 2022, Jan 2023 groups: relative lease prices drop by $2k to $5k
- $\implies$ short-run incidence for lease credits split between firms and consumers

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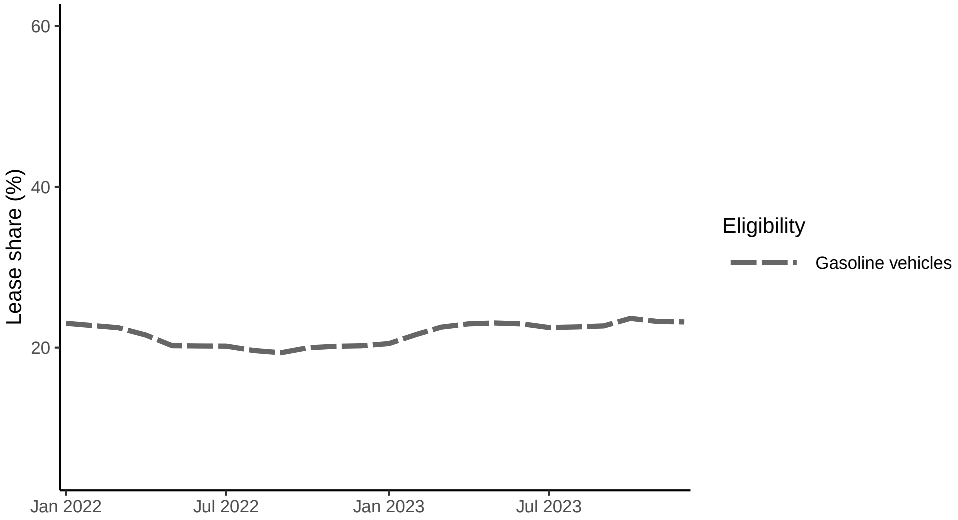
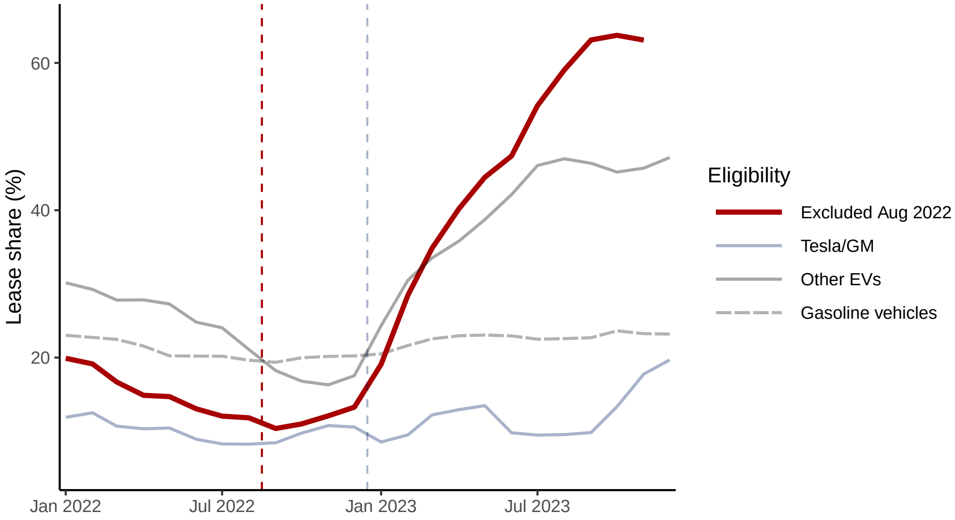
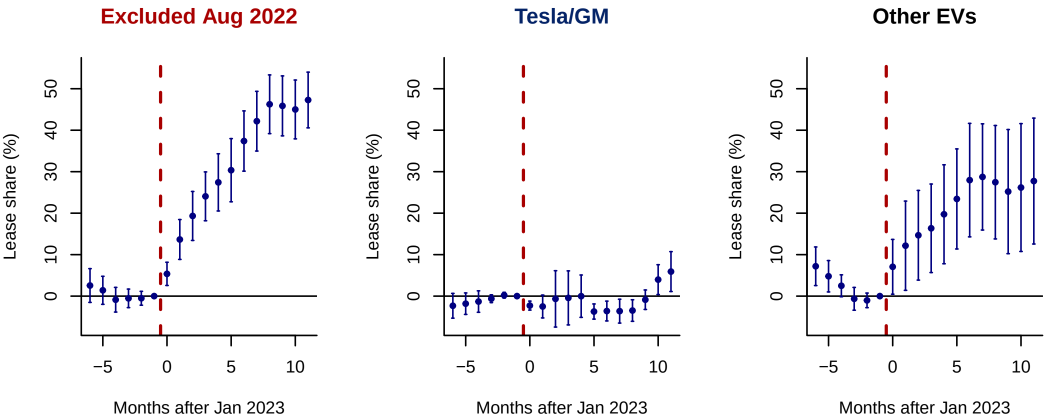
Lease shares for gas vehicles: slight increase over 2023



Trends: lease shares, by eligibility group



Event studies: lease shares



- Aug 2022 group: semi-elasticity of substitution ≈ 45% / -$5k relative price ≈ -10% / $1000

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5. **Equilibrium model**
   - **Model setup**
   - Welfare and optimal policy
6. Counterfactuals
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Model overview

Question: effects of counterfactual changes in EV subsidies?

Approach:

- Static, partial equilibrium, quasilinear utility, lump-sum revenue recycling (MCPF = 1)
- Nested logit demand, Nash-Bertrand supply
- Choice set: 2023 new vehicle submodels + outside option

Comments:

- To focus on trade restrictions, assume all buyers income-eligible
- Short / medium-run model
  - Not very short-run (inelastic supply)
  - Not long-run (model entry, supply chain adjustment, learning-by-doing, int'l responses)
  - Long run: Linn (2022), Head et al. (2024), Barwick et al. (2023, 2024)
- Abstract from interactions with CAFE/GHG standards (see Linn 2022)

Model structure

- **Demand** (consumer i, choice j, powertrain g, class c, submodel k, purchase subsidy τ)

$$
\begin{aligned}
U_{ij} &= \xi_j - \alpha(p_j - \tau_j) + \epsilon_{ij} \\
\epsilon_{ij} &= \zeta^g_{ig(j)} + (1-\sigma^g)\zeta^c_{ic(j)} + (1-\sigma^g)(1-\sigma^c)\zeta^k_{ik(j)} + (1-\sigma^g)(1-\sigma^c)(1-\sigma^k)\tilde{\epsilon}_{ij} \\
q_j &= s_{j|k(j)} s_{k(j)|c(j)} s_{c(j)|g(j)} s_{g(j)} \times M
\end{aligned}
\tag{1}
$$

- **Supply** (firm f, portfolio $\mathcal{J}_f$, lease subsidy κ_j)

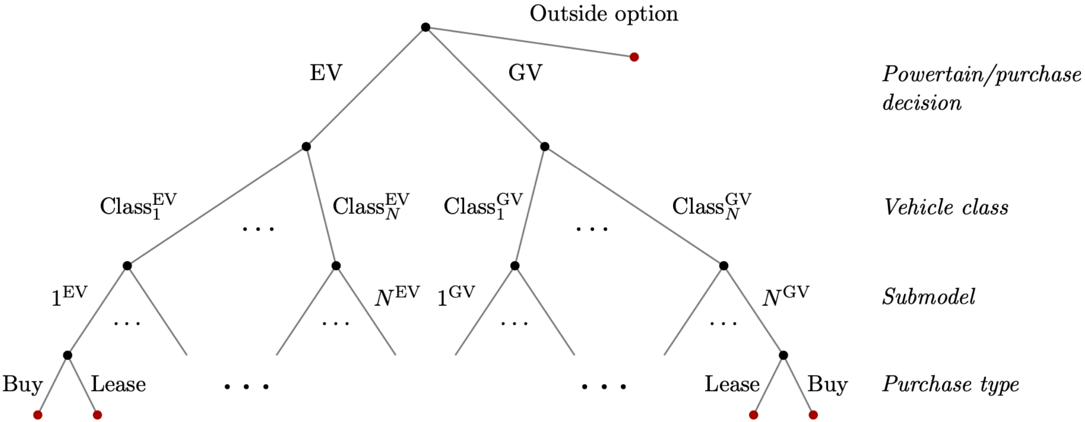
$$
\max_{p_{j|j\in\mathcal{J}_f}} \sum_{j\in\mathcal{J}_f} (p_j - c_j + \kappa_j) \cdot q_j(p_j; \boldsymbol{p_{-j}}, \boldsymbol{\tau})
$$

- Firm f FOC for choice $j \in \mathcal{J}_f$:

$$
q_j + \sum_{r\in\mathcal{J}_f} (p_r - c_r + \kappa_r) \frac{\partial q_r}{\partial p_j} = 0 \tag{2}
$$

- **Equilibrium**: **p** s.t. when f faces (1) and takes competitor prices given, p_j satisfies (2).

Demand: nested logit



Identification and estimation

- Assume households buy every six years $\Rightarrow$ total market size $= 22$ million/year
- Parameters to estimate:
  - Non-price attributes ($\boldsymbol{\xi}$)
  - Price response and nested logit $(\alpha, \sigma^k, \sigma^c, \sigma^g)$
  - Marginal costs ($\boldsymbol{c}$)
- Iterate to convergence:
  - Back out non-price attributes ($\boldsymbol{\xi}$) given $\{\alpha, \sigma^k, \sigma^c, \sigma^g\}$ (Berry 1994)
  - Choose $\{\alpha, \sigma^k, \sigma^c, \sigma^g\}$ given $\boldsymbol{\xi}$ to match moments (minimum distance)
- Construct demand ($\partial q_j / \partial p_r$)
- Back out marginal costs ($\boldsymbol{c}$) from FOC

Identification and estimation

- Moments to match:
  - Second-choice powertrain (informative about EV-GV substitution σ^g)
    - 52% of EV buyers have another EV as second choice
  - Second-choice class (informative about vehicle class substitution σ^c)
    - 33% of EV buyers have another EV of the same vehicle class as second choice
  - Model-level own-price elasticity (informative about cross-model substitution α, σ^k)
    - -5.36 (Grieco et al. 2023)
  - Match event study estimates (informative about purchase-lease substitution σ^k)
    - EV lease shares increase 39 percentage points with $-5,677 decrease in relative lease prices

- Non-price attributes: match July/August 2023 market shares

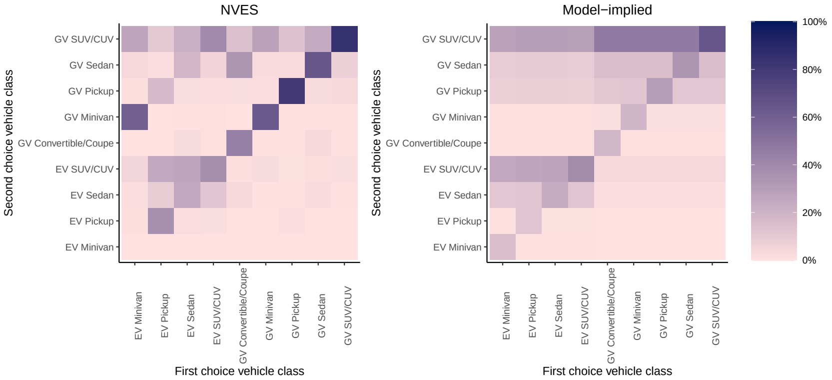
Model results: parameter estimates

Parameter	Description	Value
α	Price response parameter	0.661
σ^g	EV-GV nest parameter	0.377
σ^c	Class nest parameter	0.495
σ^m	Submodel nest parameter	0.844

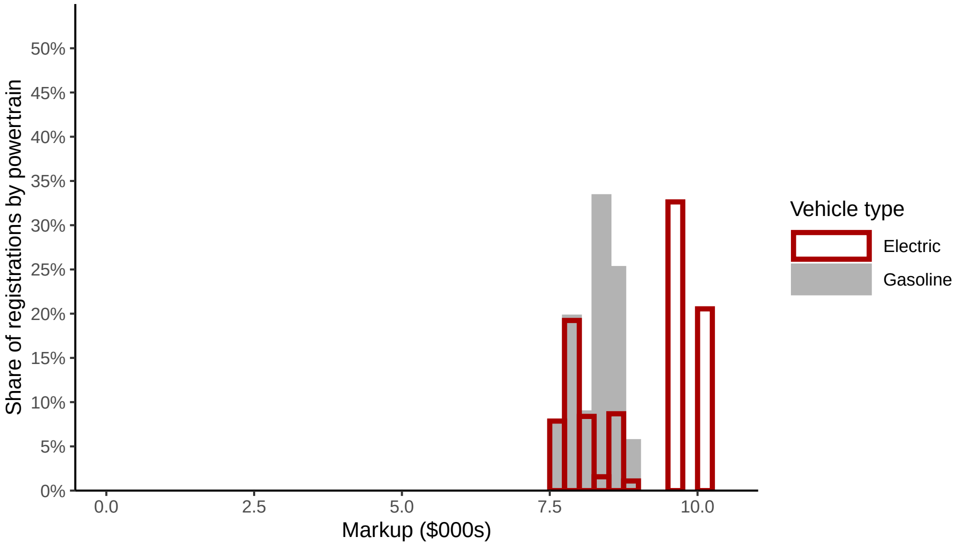
- Satisfies utility maximization ($1 > \sigma^k \geq \sigma^c \geq \sigma^g \geq 0$)
  - Result, not assumption

Model results: moments not formally targeted

- GV owners: second-choice powertrain
  - Model: 94%. Data (NVES): 97%
- Aggregate new vehicle demand elasticity
  - Model: -1.4. Comparable values (BLP 2004, Greico et al. 2023, Allcott et al. forthcoming)
- Second choices by vehicle class (heatmap)



Model results: markup distribution, by powertrain



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Market failures and optimal policy

Total surplus (MCPF $\eta = 1$, subsidy τ_j)

$$W(\boldsymbol{\tau}) = \underbrace{CS(\boldsymbol{p}, \boldsymbol{\tau})}_{\text{consumer surplus}} + \underbrace{\sum_j q_j \mu_j}_{\text{producer surplus}} - \underbrace{\eta \sum_j q_j(\tau_j)}_{\text{government spending}} - \underbrace{\sum_j q_j \phi_j}_{\text{negative externalities}}$$

- Planner's problem: maximize total surplus
  - Global or US surplus?
  - Domestic or global SCC?

- Market failures: equilibrium markup (μ_j), negative externalities (ϕ_j)

Optimal policy (global planner)

- Choice-specific Pigouvian subsidies τ_j so price = social marginal cost

$$\tau_j^{FB} = \underbrace{\mu_j - \phi_j}_{\text{"price distortion"}}$$

Optimal second-best policies that maximize US total surplus

Proposition

The second-best differentiated subsidy for choice set $\mathcal{S}$ is

$$\boldsymbol{\tau}_{\mathcal{S}}^{SB} = \underbrace{(\boldsymbol{\mu}_{\mathcal{S}} - \boldsymbol{\phi}_{\mathcal{S}})}_{\textit{price distortion}} + \underbrace{\boldsymbol{\Omega}_{\mathcal{S}}^{-1}\boldsymbol{\Omega}_{\backslash\mathcal{S}}\left(\boldsymbol{\mu}_{\backslash\mathcal{S}} - \boldsymbol{\phi}_{\backslash\mathcal{S}}\right)}_{\textit{indirect substitution}} + \underbrace{\boldsymbol{\Omega}_{\mathcal{S}}^{-1}\boldsymbol{m}_{For}}_{\textit{profit shifting}}$$

- $\boldsymbol{\Omega}$: demand derivatives $[\partial q_r / \partial p_j]$
- $\boldsymbol{m}_{For}$: vector of foreign firm profit effects $\sum_{r \in For} \frac{\partial \pi_r}{\partial \tau_j}$

Optimal second-best policies that maximize US total surplus

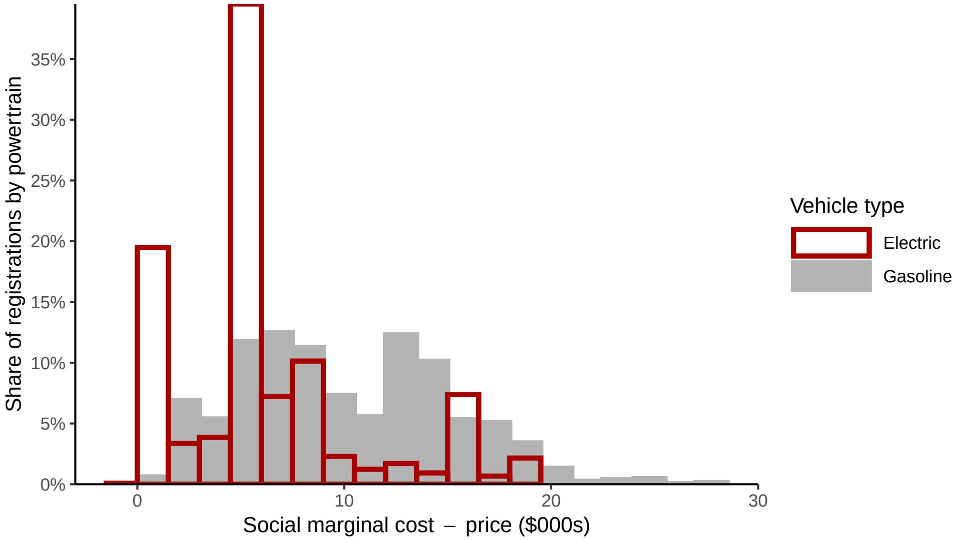
Proposition

The second-best uniform subsidy for choice set $\mathcal{S}$ is

$$\tau^{SB,U} = \underbrace{(\bar{\mu}_{\mathcal{S}} - \bar{\phi}_{\mathcal{S}})}_{\text{price distortion}} - \underbrace{(\bar{\mu}_{\setminus\mathcal{S}} - \bar{\phi}_{\setminus\mathcal{S}})}_{\text{indirect substitution}} - \underbrace{\left(\sum_{j\in\mathcal{S}} \frac{dq_j}{d\tau}\right)^{-1} \left(\sum_{j\in For} \frac{d\pi_j}{d\tau}\right)}_{\text{profit shifting}}$$

- $\bar{x}_{\mathcal{S}}$: demand response-weighted mean over $\mathcal{S}$

Wide dispersion of social marginal cost – unsubsidized price



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6. **Counterfactuals**
   - **Turn off IRA EV credits**
     - **Return to pre-IRA policy**
     - **Eliminate EV credits**
   - Relax trade restrictions
   - Constrained optimal EV tax credits
7. Conclusions

Turn off IRA EV credits: counterfactual descriptions

Scenarios:

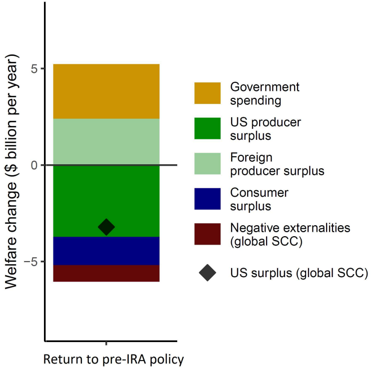
(1. IRA: April–December 2023 eligibility)

2. Pre-IRA credits with phaseout (as of July/August 2023)

- Tesla & GM: no credits
  - Toyota & Ford: $7,500 / 4
  - BMW & Stellantis: $7,500 / 2
  - All others: full $7,500

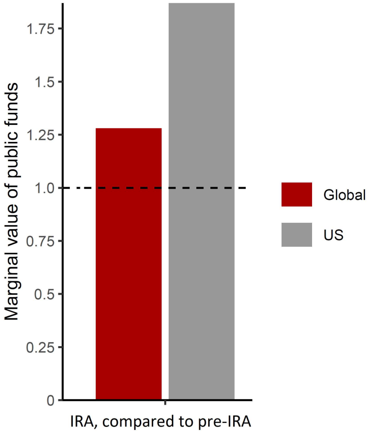
3. No EV credits

Return to pre-IRA policy: counterfactual distributional effects

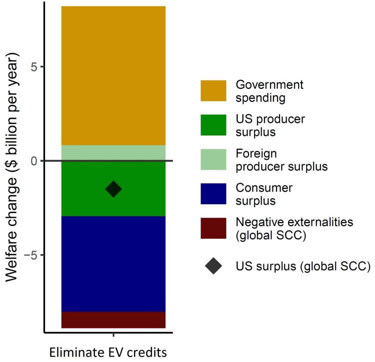


- Additionality: $\frac{\Delta G}{\Delta \text{EVs}} = \frac{\$2.84\text{bn}}{89{,}000} = \$32,000$ per EV

Return to pre-IRA policy: counterfactual MVPFs

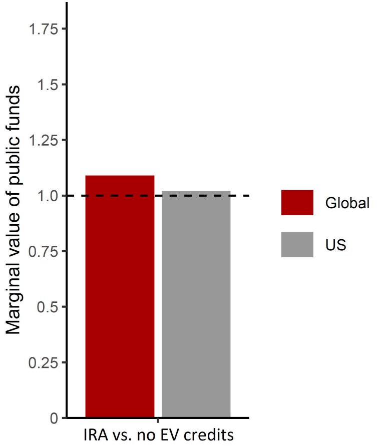


Eliminate EV credits: counterfactual distributional effects



- Additionality: $\frac{\Delta G}{\Delta \text{EVs}} = \frac{\$7.38\text{bn}}{317{,}000} = \$23,000$ per EV

Eliminate EV credits: counterfactual MVPFs



Agenda

1. Background
2. Data
3. Descriptive facts
4. Event studies
5. Equilibrium model
6. **Counterfactuals**
   - Turn off IRA EV credits
   - **Relax trade restrictions**
   - Constrained optimal EV tax credits
7. Conclusions

Counterfactuals: trade restrictions

Scenarios:

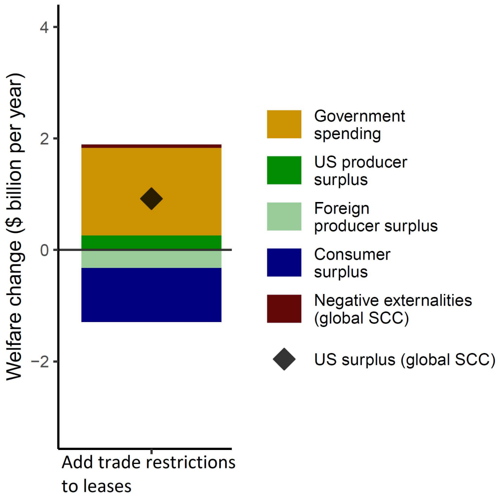
(1) IRA

(2) IRA, close leasing loophole (mostly):

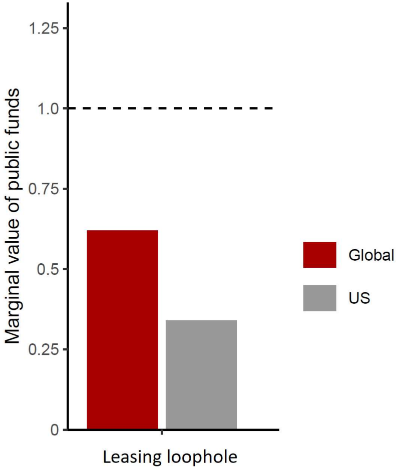
- Add trade restrictions to leasing foreign vehicles
- (Retain leasing loophole for income and MSRP conditions)

(3) IRA, remove trade restrictions on purchases

Distributional effects of relaxing trade restrictions



MVPF of leasing loophole, global v. US planner



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Counterfactuals: constrained optimal EV tax credits

Motivation:

- Gain from differentiated subsidies?

Caveats:

- Depends on externality assumptions
- Maintain trade restrictions (30D)

Counterfactuals: constrained optimal EV tax credits

Scenarios:

1. IRA

- $\Rightarrow \bar{\tau} \approx \$7,180$

2. US-optimal uniform EV subsidy

- Maximize domestic surplus at domestic SCC
- $\Rightarrow \bar{\tau} \approx \$6,355$

3. US-optimal differentiated EV subsidy

- Maximize domestic surplus at domestic SCC
- $\Rightarrow \bar{\tau} \approx \$8,916$

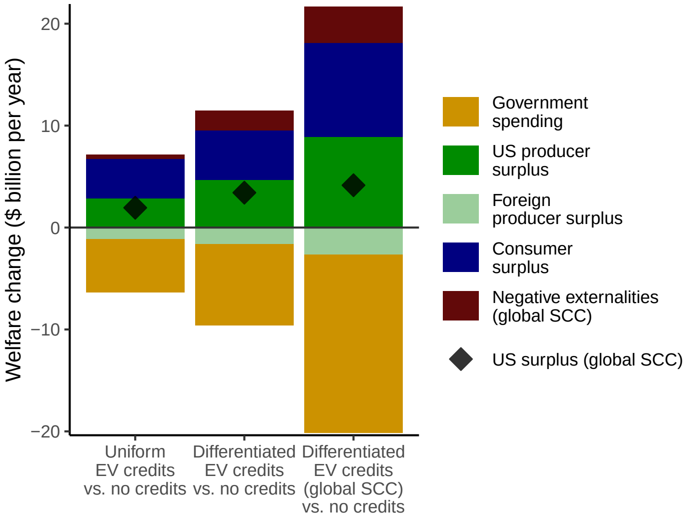
4. US-optimal differentiated EV subsidy (global SCC):

- Maximize domestic surplus at global SCC
- $\Rightarrow \bar{\tau} \approx \$14,331$

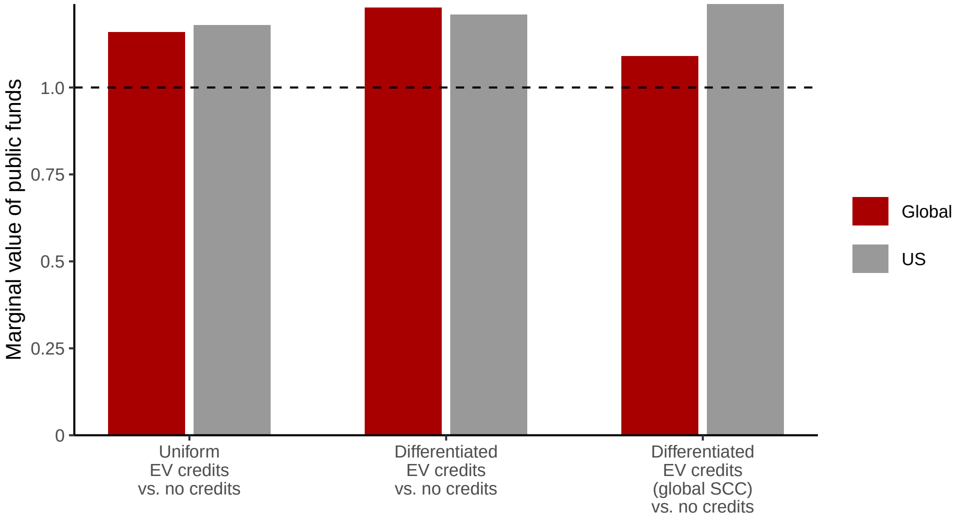
Decomposition of second-best uniform subsidies

	MCPF = 1.0, SCC = $28	MCPF = 1.4, SCC = $28	MCPF = 1.0, SCC = $241	MCPF = 1.4, SCC = $241
Price distortion	**$2,268**	$1,431	-$6,562	-$4,884
Indirect substitution	**$892**	$494	$13,293	$9,051
Subtotal	***$3,160***	*$1,925*	*$6,731*	*$4,167*
Profit shifting	**$3,195**	$2,572	$2,961	$2,462
Tax distortion	**–**	-$3,425	–	-$3,570
Uniform subsidy	**$6,355**	$1,072	$9,693	$3,058

Distributional effects of optimal EV subsidies



MVPFs of optimal EV subsidies



Agenda

Conclusions

- Motivation: evaluate IRA trillion-dollar marriage of environment + industrial policy
  - Future? Use “scalpel and not a sledgehammer” (House Speaker Mike Johnson)

- Descriptive patterns:
  - EV neg externalities (v. gas vehicles): low at global social cost of carbon, high at US SCC
  - Similar externality dispersion within EVs as within gas vehicles

- Event studies:
  - Economic incidence on consumers
  - Giant substitution to leasing

- Equilibrium model (short/medium run):
  - IRA EV credits \$1.02 to \$1.87 benefits per taxpayer dollar
  - 25% to 33% additional (66% to 75% inframarginal)
  - “Leasing loophole” low returns
  - Tension between trade/environment, foreign/domestic
  - Large gains from differentiated EV tax credits (or pricing externalities)