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

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Abstract

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We examine the implications of alterations in eligibility for tax credits under the Inflation Reduction Act (IRA) on the outcomes of the electric vehicle (EV) market. Notably, consumer tax credits necessitate that manufacturing content originates from domestic or allied suppliers, a practice often called "friendshoring." Two primary findings have surfaced from our analyses. Firstly, it appears that vehicle prices change little in response to credit eligibility restrictions, implying that the incidence of these credits is primarily on consumers. Secondly, over a year following the policy modification, there is no statistically significant effect on registrations that would disproportionately favor EVs produced in the United States. Our evidence indicates that this lack of discernible effect may be attributed, in part, to supply constraints during the initial implementation of the policy. Subsequently, supply constraints are exacerbated by the existence of a loophole allowing manufacturers to circumvent friendshoring restrictions through leasing arrangements. The current share of US assembly in the domestic EV market is approximately on par with pre-IRA levels.

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We relate short-term trends in US electric vehicle (EV) market outcomes to changes in eligibility for tax credits under the Inflation Reduction Act (IRA), using near-real time data. As the most aggressive climate change policy in US history, the IRA has potential to galvanize clean energy markets and greenhouse gas emissions. The IRA has faced domestic and international scrutiny, however, partly due to its reliance on clean energy subsidies rather than carbon prices, and due to its requirements that supply chains come from US or allied suppliers ("friendshoring"). More broadly, domestic content restrictions represent a prevalent policy with limited justification from empirical evidence. The EV tax credits represent an important element of the IRA, and ex post analysis of their effectiveness and efficiency is essential to understand how US industrial policy is working.

EV tax credits constitute one of the IRA's largest investments. The Joint Committee on Taxation projects the cost of these credits to exceed $72 billion (Committee for a Responsible Federal Budget 2023). The Congressional Budget Office originally estimated that the IRA would cost $375 billion over a decade. Subsequent analysis has increased that ten-year cost estimate to exceed $900 billion, due in part to high takeup of the EV credits (Bistline et al. Forthcoming).

The IRA provides two distinct EV tax credits, which each generate incentives for manufacturers and consumers. The more stringent "30D'" credit, named for the relevant section of the tax code, provides up to $7,500 per EV based on meeting thresholds for four variables—the share of battery and critical materials from the US and allied sources, vehicle prices, and buyer incomes. The EU and other US allies have expressed discontent over such IRA domestic content restrictions (Grimm et al., 2023; Kleimann et al., 2023). The "45W'" IRA EV credit also provides up to $7,500 per EV for leased vehicles, but lacks conditions based on domestic content, vehicle price, buyer income, or anything else. Thus, a transaction which does not meet the 30D restrictions can circumvent them by leasing the vehicle and therefore qualifying for 45W. A vehicle cannot qualify for both the 30D and 45W credits, though some EVs qualify for $7,500 credits under earlier legislation. The timing of implementing these requirements varies by submodel, a fact we exploit in analysis.

The IRA is part of a "Buy-American" strategy. The Biden administration has a larger push for a "twenty-first-century American industrial strategy—a strategy to strengthen our supply chains [and] rebuild our industrial base across sectors, technologies, and regions of this country" (Atlantic Council, 2021). Senator Joe Manchin, who provided the pivotal vote ensuring the passage of the IRA, emphasized a similar point in his motivation for supporting the bill: "the increased risk of geopolitical uncertainty demands that we turn our focus to increasing U.S. energy production and bringing good paying energy and manufacturing jobs back to America" (Manchin, 2022). Specificaly as they concern the automotives sector, these statements are complemented by the ongoing import tariff rate of 27.5% on Chinese EVs, which began under the Trump administration and was continued by the Biden administration Wilmot 2024.

Several features make the IRA a core part of this strategy. First, the consumer tax credits condition on North American assembly, which for EVs overwhelmingly means assembly in the US since few EVs are made in Canada or Mexico. Second, as of April 2023, consumer tax credits are

contingent on also satisfying a sourcing requirement for battery components, with a sufficiently large fraction of inputs having to be supplied from from the US or allied countries. Finally, due to the IRA, as of January 2023, two popular Tesla models (Model 3 and Model Y) are eligible for the tax credits and 100% of their sales in the US come from US assembly plants.

We organize our analyses into three parts. First, we assess how the EV tax credits affect EV subsidy-exclusive prices and registrations. Knowing the change in EV prices is important to understand the credits' incidence, and knowing the change in EV quantities is important to understand the extent to which industrial policy shifted demand towards US made vehicles. We compare price and quantity outcomes over time based on groups of vehicles gaining and losing eligibility for credits.

Our estimates of subsidy-exclusive price changes from registration data in California suggest that manufacturers passed through the 30D consumer tax credit to consumers. Notably, we find similar evidence for Tesla, which commands large market shares and thereby market power in the EV market. We arrive at these conclusions by noting a lack of a significant change in subsidy-exclusive prices in event studies around three events, two of which excluded manufacturers from credits and one of which re-included manufacturers from tax credits. This implies that the effective price of EVs, after application of the tax credit, fell substantially in January 2023 when Tesla and GM regained accesss to consumer tax credits and increased for a subset of foreign-assembled models or models with high foreign content in August 2022 and April 2023. Despite this price reduction, we fail to find systematic impacts of the tax credits on EV quantities. Taken literally, the confidence regions would exclude conventional estimates of own-price demand elasticities. This is despite the fact that, over the longer run, the EV share of light-duty vehicles and light-duty trucks has trended upwards in both California and the national markets. Our null findings for the impact of 30D credits on quantities are specific to the time period roughly from mid-2022 through mid-2023 when the series of IRA-related policy changes went into effect. Second, we investigate potential explanations for why the IRA EV consumer tax credits could have limited impacts on EV quantities. While we discuss these interpretations cautiously given differential trends for groups of EVs, we focus on three potential explanations: consumer incomes that make buyers ineligible for the 30D tax credits; supply chain constraints that make new vehicle supply inelastic; and substitution to leasing and the 45W credit as a strategy to avoid the various 30D conditions.

Available evidence suggests that most current EV buyers' incomes qualify for the credits, so buyer incomes would not account for limited quantity or price impacts of the 30D credits. Additionally, while supply constraints were binding before mid-2002, several data sources suggest that supply constraints were relaxing in mid-2022, and that supply in late 2022 was sufficiently elastic to respond to credits. Leasing of EVs, by contrast, skyrocketed in response to these tax credit incentives, especially by manufacturers for EV models that lost eligibilty to consumer tax credits.

Third, we assess patterns in domestic assembly trends. The IRA EV tax credits seek in part to encourage supply chain sourcing from North America. We find that the market share in California of EV vehicles made in the US has not substantially increased beyond the 74 percent market share

prior to the IRA in early 2022.[1] Whereas assembly in Canada and Mexico would also satisfy the NA requirement, there is little assembly of battery EVs and plug-in hybrid EVs in these countries.[2] This pattern differs for internal combustion engine vehicles, where vehicles assembled in Canada and Mexico command a more significant market share.

We build on a few literatures. We provide the first estimates of how the IRA's EV subsidies affect prices. We build on existing discussions of the IRA's EV subsidies (Bown (2023b) and Buckberg 2023), including national graphs of leasing rates through the first half of 2023 (Bown 2023a). Jia Barwick et al. (2023) study impacts of global EV battery subsidies, and others study earlier US national and state EV subsidies, especially California's (Jenn et al. 2013, 2018; Clinton and Steinberg 2019; Lohawala 2023).

More broadly, we examine a prominent case of domestic content restrictions, which contributes to a limited empirical literature on their use. Head et al. (2022) study rules of origin in a regional trade area like the North American Free Trade Agreement (NAFTA). Conconi et al. (2018) study the role of input-output links in NAFTA's rules of origin. Cox and Acosta (2023) study the effects of the Buy American Act of 1933 on firm-level sourcing decisions.

We proceed as follows. Sections 1 describes the relevant institutions. Section 2 discusses data. Section 3 discusses market outcomes, Section 4 discusses explanations, Section 5 concludes with a broader discussion.

1 Background

1.1 EV Markets

Electric vehicles (EVs) currently account for 14 percent of global new car sales, up from 5 percent in 2020 (IEA 2023). China dominates the market—60 percent of global EV sales occur in China, and China accounts for a third of all exported EVs globally (IEA 2023). China also dominates the supply chains for battery minerals and components (Leruth et al. 2022).

The Chinese dominance has led to geopolitical concerns (Bown 2023b). US National Security Adviser Jake Sullivan (2023) said in a major speech, "Clean-energy supply chains are at risk of being weaponized in the same way as oil in the 1970s, or natural gas in Europe in 2022. So through the investments in the Inflation Reduction Act and Bipartisan Infrastructure Law, we're taking action" (Sullivan, 2023).

[1] We find a moderate increase from 70 percent to 73 percent in the US assembly share for the national EV market. These values, however, are computed from model-level assembly location data in EV-Volumes and are not as granular as each vehicle's VIN based assembly plant information obtained in the California registration data; for this reason, we have higher confidence in the assembly share computed based on the California market.

[2] Notable exceptions include the Ford Mustang Mach-E, assembled in Mexico, and the Chrysler Pacifica partial hybrid EV, assembled in Canada.

1.2 Clean Vehicle Credits

Clean Vehicle Credits are income tax credits for new vehicles under 14,000 pounds with external power, including fully EVs, plug-in hybrid EVs, and fuel cell vehicles.[3] Because the credits are non-refundable, only taxpayers with tax liability can use the credits. The 2009 American Recovery and Reinvestment Act (ARRA) established credits of up to $7,500 for the first 200,000 EVs each manufacturer sold. Tesla and General Motors exceeded that cap and lost credit eligibility in 2018 and 2019, respectively.

The IRA became law on August 16, 2022. Two sections of the IRA include tax credits for new EV purchases: 30D and 45W. Section 30D offers up to $7,500 individual (not business) tax credits for new EV purchases, under four conditions. Currently, for a vehicle to qualify for the 30D credit, at least half of the vehicle's battery components must be manufactured in the US or a country with which the US has a free trade agreement. Additionally, at least 40 percent of the battery's critical materials must be processed in the US or a country with which the US has a free trade agreement. Furthermore, the vehicle's Manufacturer's Suggested Retail Price (MSRP) must be below $55,000 for cars and $80,000 for SUVs and trucks. Finally, the buyer must have income below $300,000 (for married couples filing jointly), $225,000 (for household heads), or $150,000 (for all other taxpayers).

These 30D eligibility conditions have changed over time. The North American assembly requirement began on August 17, 2022. On January 1, 2023, the 200,000 vehicle limit was removed and both the household income and MSRP caps appeared. The battery mineral restrictions appeared on April 18, 2023.

Section 45W of the IRA offers $7,500 tax credits for businesses (not individuals) for new EV purchases under 14,000 pounds.[4] The US Treasury announced that starting January 1, 2023, firms could claim the 45W credit for leasing EVs to individuals (Internal Revenue Service, 2022). Section 45W credits are available for all vehicles, with no conditions based on sourcing, income, or price. Thus, new vehicle transactions that would not qualify for an individual tax credit under Section 30D could still qualify for a commercial tax credit under Section 45W if the vehicle is leased.

In dealer interviews and online discussions, we have heard anecdotes of dealers encouraging consumers to lease a vehicle and then immediately afterwards buy out the lease. This would indirectly allow the 45W credit to qualify for purchased vehicles. We have not found systematic statistical evidence measuring the existence or prevalence of this practice. See Section 4.3 for more details.

Different processes transmit the 30D and 45W credits to consumers. Consumers claim the 30D credit on their income tax form that is filed in the calendar year after the purchase. For example, a consumer who purchased an EV in June 2023 and qualified for 30D would receive the $7,500 as a credit when filing taxes in April 2024[5]. The 45W credit goes directly to the leasing firm or auto

[3] The Toyota Mirai is the only available fuel cell EV as of November 2023; 2,661 sold nationwide from January through October.

[4] Section 45W also allows $40,000 tax credits for larger vehicles, which we do not study here.

[5] As the credit is nonrefundable, the buyer must also owe at least the full credit amount in taxes to take advantage of the 30D credit (Internal Revenue Service, 2023)

manufacturer. Most auto manufacturers have begun providing $7,500 rebates to consumers that lease EVs, and thereby pass the 45W credit through to consumers. Notably Tesla did not provide these leasing rebates until October 2023.

Figure 1, building on Figure 3 from Buckberg (2023), shows which vehicles have been eligible for credits across the multiple policy changes since the initial passage of the IRA. Rows show models and columns show time periods. Cells with shading indicate model eligibility. Lighter shading indicates that a model is eligible for only a fraction of the possible $7,500 amount. Unshaded cells represent ineligible models.

In the event studies below, we focus on three changes in eligibility:

(1) **August 2022 Exclusion**. This group includes models that lost eligibility for tax credits on August 17, 2022. These submodels originally had eligibility through the Energy Policy Act of 2005 and the American Recovery and Reinvestment Act of 2009. These submodels become ineligible because they are assembled outside of North America. This group includes some Audi, BMW, Mercedes, and Nissan models, and all Hyundai, Kia, Lexus, Polestar, Porsche, Subaru, Toyota, and Volvo models.

(2) **January 2023 Inclusion**. This group includes models that were ineligible before January 1, 2023 under the American Recovery and Reinvestment Act of 2009 credit. They became eligible because of the removal of the manufacturer-level 200,000-vehicle limit. This group includes the Chevrolet Bolt and the Tesla Models 3 and Y.

(3) **April 2023 Exclusaion**. This group includes models that were eligible before April 18, 2023 but lost part or all of the credits due to battery sourcing requirements. This includes some Audi, Ford, and Nissan models and all Rivian models.

We note that a few EVs belong to groups besides these three main groups that are our focus. A few high priced vehicles became excluded from 30D credits in January 2023 due to the MSRP cap; some vehicles were always eligible for tax credits; and a small group of EVs was always excluded from the consumer tax credits. Online Appendix C provides further details.

2 Data

We combine several data sources; Appendix A provides details. Data from the US Department of Energy, describe the amount of Clean Vehicle Credit each EV model qualifies for in each month (Department of Energy 2023a,b).

The California Department of Motor Vehicles (DMV) provides our primary data on vehicle registrations. For each registration, these data report the date, transaction price, purchase method (lease or purchase), and vehicle identification number (VIN) prefix. A VIN prefix uniquely identifies the vehicle make, model, model year, and other attributes. We have data from three DMV registration cross-sections: October 2022, July 2023, and October 2023, each describing all vehicles registered at the time of the cross-section (most of which had registrations filed in earlier months)..

We use NHTSA (2023)'s VIN decoder to determine the gross vehicle weight, powertrain type, and assembly location corresponding to each VIN prefix. We limit the analysis sample to vehicles with weights below 10,000 pounds, which mostly excludes heavy-duty vehicles.

For the case of new vehicle transactions, dealerships in the California registration data rather than buyers report the transaction to the DMV. This may increase accuracy of date and price values in the registration data. The California reported price represents the "full cost price to the buyer, excluding sales tax, license fees, or financing costs" (California DMV 2023). This price would not reflect any concessionary prices paid for trade-in vehicles, and it may not reliably reflect dealer cash rebates. If dealer cash rebates vary systematically with a model's tax credit eligibility, this would affect economic incidence.

We define a "submodel" as the combination of make, model, series, and drivetrain (internal combustion engine, battery EV, or hybrid EV), as reported in the DMV data. For example, the Hyundai Ionic 5 has three submodels (SE, SEL, and Limited), and the Nissan Leaf has four (S, SV, SV Plus, and SL Plus). Tesla does not have different submodels recorded in the California registraiton data within the four models which occur in our data (S, X, Y, and 3).

We aggregate the California registration-level microdata to a submodel-by-month panel for analysis. This analysis file reports registration counts, mean sales price, share leased, and eligible credit amount for all new vehicle sales in California. Our panel covers October 2021 through August 2023. Panel (a) of Table A1 presents descriptive statistics on this dataset. For all vehicles, we have 34,708 total submodel-by-month observations on 1,769 submodels. For EVs specifically, we have 2,587 submodel-by-month observations on 198 submodels.

We report nominal prices, without any inflation adjustment. The price variable we receive is top-coded at $96,700. For each submodel, we define all prices to be missing if more than half of the individual transaction prices are top-coded. Otherwise, a submodel-by-month price observation equals the mean of reported sales prices (i.e., excluding leases) across all transactions, including top-coded values.

In addition to California-specific data, we make use of extensive national vehicle transaction from Cox Automotive. These data cover a large number of transactions, both purchase and lease, and provide detailed information on each (including the VIN of the vehicle, the MSRP and price of the vehicle, the down payments and monthly payments where applicable, and reported APR). Using these data, we are able to expand our analysis beyond California; however, this occurs with some loss of generality, as the sample provided by Cox is not entirely representative. In particular, it has imperfect coverage of Tesla (especially Tesla leases) and other startup EV manufacturers such as Lucid and Rivian. To account for this, our analyses from Cox reweight submodel-level observations at the make level to match what is reported in Edmunds (2023a), which reports national sales by make.

Additionally, we collect nationwide model-by-month sales for EVs, including plug-in hybrids, from EV Volumes (2023). We collect model-by-month "days to turn" (i.e., the mean time between delivery and sale for vehicles sold in a given month) and share leased for all vehicles, including non-

EVs, from Edmunds (2023b). The Edmunds data aggregate across powertrains within a model. When analyzing EVs in those data, we exclude models that have both electric and gasoline powertrains, such as the Ford F-150 and Jeep Wrangler. Panel (b) of Table A1 presents descriptive statistics on the nationwide data.

The Edmunds days-to-turn data exclude Tesla. The Tesla website, however, reports estimated delivery dates. Using the Tesla website, the website tomsguide.com, and the Internet Archive (Tesla 2023; Tom Pritchard 2023; The Internet Archive 2023), we construct delivery wait times for each Tesla model in each month from October 2021 to August 2023.

In summer 2023, we surveyed US dealerships to determine EV wait times, prices, and qualitative characteristics of EV markets. Research assistants began with the script, "I'm interested in purchasing an electric or plug-in hybrid vehicle soon. If I were to pay in cash, what's the soonest that I could drive home a *[model name]* of any configuration?" Research assistants then asked about a list of popular EV submodels and recorded estimated delivery dates and prices for each. In addition, research assistants noted other relevant additional information that dealerships provided. We contacted five to ten dealerships in each of several metro areas that several data sources suggested had the largest market shares of EVs and that provided some geographic diversity—St. Louis, San Jose, Minneapolis, San Francisco, Los Angeles, San Diego, New York, Houston, and Philadelphia.

We also make use of vehicle registration data from Texas, which takes the form of comprehensive VIN-level registration records between January of 2017 and October of 2023. The primary advantage of these registration data as compared to the California data is the presence of the complete VIN (allowing us to track re-registrations of the same vehicle over time). The primary difficulty is the lack of a direct indication of whether a given transaction is associated with the purchase or lease of a new vehicle. To circumvent this difficulty, we again use new vehicle data from Cox Automotive, which allows us to see transaction-level details, identified by VIN, for a subset of new vehicles. Cox data includes whether a given transaction is a lease or purchase, and so we can restrict our analysis of the data in Texas to the subset of vehicles which is identified as (initially) leased in the Cox data. The combination of these two datasets is used in Section 4.3 to examine patterns of lease buyouts after the January 2023 change to lease tax credits under 45W.California Data Validation

Our access to national registration microdata is in process but currently incomplete, so this draft focuses on California registrations. California represents 26 percent of US EV sales over our sample. Our construction of monthly registration counts has a correlation of 0.99 with sales reported by the California New Car Dealers Association (2023). The California data also correlate well with nationwide data. California registrations and EV Volumes market shares have a correlation of 0.99. California and Edmunds lease shares have a correlation of 0.76. Given this close relationship between California and all national registrations, we expect that future drafts using nationwide registration data will observe similar patterns as this analysis using California.

2.1 Descriptive Facts

Panels (a) and (b) of Figure A2 present price and registration and trends for the 10 EV models with the greatest sales in California. The legends list models from most popular at top to least popular at bottom. The registration data in Figure 4b elucidate two key facts relevnt to our analysis. First, Tesla represents 60 percent of the California market and 50 percent of the US market over our sample. As shown in Figure 4b, Tesla Models Y, 3, X, and S are the first, second, fifth, and ninth most popular EVs. Second, Tesla registrations have a sawtooth pattern over time, with the most registrations at the end of each quarter. This pattern reflects quarterly reporting incentives, which cause sales of Tesla but not other manufacturers to have this sawtooth pattern.

The price data in Figure 4a illustrate one key trend that affects our analysis: mean EV prices dropped substantially from mid-2022 through mid-2023. Tesla prices decreased the most, but other models' prices also decreased visibly.

This reflects a "price war" (Cao, 2023)that Tesla started in late 2022. In anticipation of the Models 3 and Y regaining 30D eligibility at the start of 2023, Tesla dropped prices on both models throughout December to discourage consumers from delaying purchases. Tesla further reduced some prices in January by up to $13,000 (Boudette, 2023). Other leading EV manufacturers followed by drastically reducing prices (Shepardson and Nair, 2023; Bernstein, 2023).

3 Relationship of EV Prices and Quantities to Credit Eligibility

This section relates changes in EV prices and quantities to changes in 30D EV tax credit eligibility. We focus on three eligibility changes—the August 2022 exclusion from credit eligibility of vehicles assembled outside of North America, the January 2023 inclusion of Tesla and GM among eligible manufacturers, and the April 2023 exclusion of models with insufficient battery content from free-trade areas.

For each of the eligibility changes separately, we estimate the following event study equation:

$$y_{jt} = \sum_{r=\underline{R}}^{\overline{R}} \tau_r C_j \cdot 1\left\{t - r = t_j^*\right\} + \beta X_{jt} + \phi_j + \nu_t + \varepsilon_{jt} \tag{1}$$

Here, j indexes submodels and r and t index months. Define t^* as the month when submodel j's eligibility changes, and define $\underline{R}$ and $\overline{R}$ as the beginning and end of an event window around the eligibility change. Typically, we set $\underline{R} = -6$ and $\overline{R} = 6$; for the April 2023 eligibility change, $\overline{R} = 3$, and we explore longer post-event outcomes for the other events. Define y_{jt} as an outcome variable corresponding to the mean sales price or natural log of registrations. Define C_j as the absolute value of vehicle j's 30D eligibility change, divided by $7,500. For example, a vehicle that becomes eligible for the full $7,500 tax credit has $C_{jt} = 1$; a vehicle where elgibility falls from $7,500 to $3,730 has $C_{jt} = 0.5$. Define X_{jt} as Tesla $\times$ month-of-quarter indicators, which control for the quarterly sawtooth pattern in Figure A2. These are most relevant for the January 2023 eligibility change,

since Tesla did not change eligibility in the August 2022 or April 2023 events.[6] Finally, define ϕ_j and ν_t as submodel and month-of-sample fixed effects. We normalize the reference category for $\tau = -1$ to equal zero. Each graph shows a separate eligibility change. We cluster standard errors by model.

The regressions only include observations inside the event window, i.e., such that $t_j^* - \underline{R} \leq t \leq t_j^* + \overline{R}$. All regressions exclude (j,t) pairs with fewer than 25 transactions. The regressions with price as the dependent variable further exclude (j,t) pairs with fewer than 10 valid sales. We primarily analyze sale but not lease prices since California registration data lack full lease terms.

We weight all observations for a submodel j by its mean monthly registrations in the sample. Thus, τ roughly represents the mean effect of credit eligibility on market aggregate price or registrations. Unweighted results would be more influenced by low-volume submodels and would be sensitive to the definition of a submodel.

In each event study, the treated group consists of the EV submodels experiencing a 30D eligibility change. We report two sets of results, using different comparison groups—one set of results comparing treated EVs against ICE vehicles (including non-plug-in hybrids), excluding all other EVs from the regressions; and the other comparing treated EVs against non-treated EVs. Each comparison has certain advantages and disadvantages, discussed below. The appendix also reports quasi-placebo estimates comparing non-treated EVs against ICE vehicles.

Equation (1) estimates the effect of tax credits within a submodel, using submodel fixed effects. The analysis therefore excludes any extensive margin effects of tax credits on the introduction of new models or submodels. We believe this is appropriate because the introduction of new models and submodels requires extensive lead and planning time, while these events had very limited advance notice.

We primarily analyze each eligibility change separately since the eligibility changes could have heterogeneous pass-through rates. For example, the January 2023 eligibility change affects Tesla, which has substantial EV market share and market power. Manufacturers affected in the August 2022 or April 2023 eligibility changes have smaller EV market shares. The appendix does report estimates pooling the eligibility changes into one regression.

Pass-through is important for studying incidence and other important topics in indstrial organization and international trade (Fabra and Reguant 2014). We briefly discuss what the shape of event study graphs implies about the pass-through rate. Pass-through equals the dollar increase in tax credit-inclusive prices due to a dollar increase in tax credits (Weyl and Fabinger 2013). The tax-inclusive price of a qualifying vehicle thus equals the sale price our data report, minus the (e.g., \$7,500) EV credit the buyer claims in taxes filed the following year.

A flat event study graph for sale prices therefore implies complete pass-through. While this sounds slightly counterintuitive, it is because vehicle sale prices in our data and that consumers pay dealers exclude the EV credit value, which consumers claim on the following year's personal income

[6]Each of the main event study analyses includes only EVs that changed 30D eligibility or ICE vehicles; Tesla vehicles only changed 30D eligibility in January 2023.

taxes. Hence, finding that EV credits do not affect tax-exclusive sale prices implies a pass-through rate of one. Similarly, if credits increase sale prices by the full credit amount (e.g., $7,500), then credits have a pass-through rate of zero, since they do not affect tax-inclusive prices. For events where vehicles lose credit eligibility, the reverse interpretation applies—a flat event study graph still implies complete pass-through, but an event study graph where sale prices fall implies incomplete or zero pass-through.

The EV price war that began around December 2022, discussed in Section 2.1, affects interpretation of these graphs. The price war, led by Tesla, war reflected improving EV demand. The event study graphs shade the price war period in light gray. Price changes coincident with the price war's inception may reflect market conditions more than effects of EV credits. The timing of this price war therefore obscures price effects of the January 2023 eligibility change on prices, and leaves shorter pre- and post-periods to ceanly study effects of the August 2022 and April 2023 eligibility changes.

3.1 EV Prices and Credit Eligibility

This subsection estimates the pass-through of changes in eligibility for Section 30D EV tax credits to vehicle prices.

Figure 4a shows unadjusted trends in sales prices by eligibility group. This graph shows no clear price changes after a group changes eligibility. The data do show nonlinear aggregate trends for all vehicles, echoing Panel (b) of Figure A2. Beginning in mid 2022, the data show EV price declines for vehicles affected by the August 2022 and the January 2023 eligibility changes. The price increases in the EVs that change eligibility in April 2023 primarily represent composition, with high-priced Rivian models becoming more common in mid-2022, less common later that year, and again more common through 2023.

Figure 5 estimates equation (1), with registration price as the outcome variable. The left graph of Figure 5(a) analyzes the August 2022 eligibility change. Before this eligibility change, ICE vehicles and EVs that lost eligibility had similar sale price trends. In the first few months after this eligibility change, the EVs that lost eligibility had no discernable change in price relative to ICE vehicles. As discussed earlier, since we observe tax-exclusive sale prices, this would imply complete pass-through of EV credits to tax-inclusive consumer prices. Beginning in January 2023, coincident with the beginning of this price war, EV prices fell.

The center graph of Figure 5(a) analyzes the January 2023 eligibility change, which added EV credit eligibility for vehicles that had previously exceeded manufacturing limits (GM and Tesla). Until the month before this policy reform, the EVs experiencing the eligibility changes and ICE vehicles had similar price trends. The grey shading reflects that the price war, more than EV credits, may drive price changes between EVs and ICE vehicles around January 2023

The right graph of Figure 5(a) analyzes the April 2023 eligibility change, which removed or reduced credits for vehicles with insufficient battery content from North America. After the EV price war begins, EVs that lost credit eligibility had roughly similar price trends before and after

the April 2023 eligibility change. This pattern is again consistent with complete pass-through of EV credits to tax-inclusive consumer prices.

Figure 5(b) shows the second research design, which uses EVs that did not experience an eligibility change rather than ICE vehicles, as the control group. This provides an imperfect placebo because EVs provide closer substitutes for other EVs than other ICE vehicles do, and vehicles price strategically against closer substitutes, so providing tax credits to one group of EVs may affect prices of other EVs.[7] At the same time, under the strong assumption that the EV price war caused similar shifts in prices of all EVs but had limited effects on prices of ICE vehicles, this second design would provide one possible way to separate effects of the price war and market conditions from those of EV credits.

The left graph of Figure 5(b) analyzes the August 2022 eligibility change. The graph suggests that sale prices of EV that experienced an eligibility change moved little relative to sale prices of EVs that did not experience an eligibility change. The graph shows a small but statistically insigificant price drop when the price war begins.

The center graph in Figure 5(b) analyzes the January 2023 eligibility change. EVs which gained credit eligibility, primarily Tesla, had a price decline relative to sale prices of EVs that did not gain credit eligibility. Since Tesla led the price war and the price war may have differential effects even among EVs, we remain cautious about interpreting the Tesla price changes around January 2023 as reflecting EV credits rather than broader market conditions.

The right graph in Figure 5(b) analyzes the April 2023 policy change. The pre-trends are flat and we detect no price change for EVs that lost credit eligibility in April 2023 versus those that did not, again suggesting complete pass-through.

Overall, the evidence in this subsection is consistent with complete pass-through. None of the event study graphs show that changing EV credit eligibility affects vehicle sale prices, which implies that consumers experience all of the eligibility change on prices upon claiming the credit in the next year's personal income taxes. We do interpret these estimates cautiously given the EV price war and evolving market conditions in this period.

What would complete pass-through imply about incidence of the credits? Under perfect competition, complete pass-through would imply that consumers receive all the surplus from these credits. Under oligopoly, the surplus would be shared between vehicle manufactures and consumers, with

[7]Some price changes for specific models around event dates have occurred. For example, in the month prior to becoming eligible, Tesla offered a $3,750 discount to buyers of Models 3 and Y (Bellan, 2023). Note that this price decrease, as it took effect during the last month of 2022 and prior to the eligibility change, was possibly to encourage prospective buyers who were waiting for the full 30D credit to instead purchase before the end of the year. In theory, the price caps for Section 30D eligibility could cause price decreases. We observe just one case: in January 2023, Tesla reduced Model Y prices to just under the $55,000 price cap. Just after a meeting with Tesla CEO Elon Musk, the Biden Administration reclassified crossover SUVs such as the Model Y as having an $80,000 price cap for eligibility under Section 30D. Tesla increased Model Y prices to above $55,000 immediately after the reclassification CNBC (2023). We observe no clear evidence that the price caps have caused price decreases for other models. In September 2023, Tesla reduced Model X prices so that some sales fall under the $80,000 SUV price cap, but it also reduced prices for the Model S, which is not eligible for the tax credits because it is well above its $55,000 price cap (Stafford 2023). We do not observe other models where price decreased below its Section 30D price cap.

the division depending on market structure (Weyl and Fabinger 2013).[8]

Because we detect no effect of EV credit eligibility on tax-exclusive vehicle sale prices, this section's results suggest that these eligibility changes substantially affected tax-inclusive consumer prices. Thus, one might expect this EV credit eligibility to affect EV purchases and registrations, a prediction the next section tests.

3.2 Registrations

Figure 4b plots unadjusted trends in new EV registrations, which include EV sales and leases. We again separate the three groups that had 30D EV credit eligibility changes in August 2022, January 2023, and April 2023. The vertical axis uses a log scale to capture large differences in registrations across groups. Recall that the group which became eligible in January 2023 primarily includes Tesla. Tesla, unlike other manufacturers, sells a disproportionate share of vehicles in the last month of each quarter, and Tesla's quarterly sales cycle drives this group's overall sawtooth pattern.

Figure 4b shows no obvious changes in registrations when vehicles change eligibility for EV credits. Preceding the passage of the IRA, there was a notable increase (in early 2022) followed by a decline (during summer of 2022) in registrations of Hyundai and Kia EVs. This trend is seen in the California data, and is corroborated by international trade data, which show a contemporaneous decline in EV imports from South Korea relative to Europe and Japan.

Panel (a) of Figure 6 shows event study graphs corresponding to equation (1), with log registrations as the dependent variable. The left, center, and right graphs describe the three eligibility changes. The shaded light gray in each graph covers the EV price war, beginning around December 2022. All three graphs compare EVs that gained or lost eligibility to EVs that did not change eligibility.

Figure 6, Panel (a), shows little evidence that eligibility for the 30D EV credits affected vehicle registrations. The left graph shows no statistically significant change in registrations for treated EVs. The point estimates are generally positive, suggesting a small and statistically insigifcant increase in registrations, while we would expect that loss of tax credits for treated EVs in this graph would if anything instead decrease EV registations. The month-by-month confidence intervals are wide, though they rule out a decrease of more than 20 percent. We again interpret the center graph of Figure 6, Panel (a), cautiously given that the January 2023 change in EV credit eligibility coincides with the start of the EV price war.

The right graph of 6, Panel (a), also detects no meaningful effects of EV credit eligibility on the log of vehicle registrations. The point estimates are statistically indistinguishable from zero and oscillate sign around zero. Again the month-by-month confidence intervals are wide.

[8] Under symmetric imperfect competition, the ratio of a change in consumer to producer surplus is $\rho/[1-(1-\theta)\rho]$, where ρ is the pass-through rate and θ indexes market structures. For example, $\theta = 1$ in this formula describes monopoly, $\theta = 0$ is perfect competition, and intermediate values of θ can describe monopolistic competition, Cournot, or others. A related formula relaxes the symmetry assumption (Weyl and Fabinger 2013).

Figure 6, Panel (b), describes our second research design, which compares EVs that change eligibility in a period against EVs that do not. As discussed in the previous subsection, this design has advantages and disadvantages relative to the comparison of treated EVs against ICE vehicles in the previous subsection, though looking at both designs can provide more insight than only studying one.

Figure 6, Panel (b), also suggests that EV credit eligibility had no detectable effects on EV registrations. No post-period indicator is statistically distinct from zero in any of the three graphs. The post-period coefficients vary sign about zero. Most of the point estimates are somewhat near zero, and most month-by-month standard errors rule out impacts of greater than 20%. Two of the pre-period indicators in the left graph, though not others, are significantly positive.

A related pattern worth discussing is that while data show a long-term increase in the market share of EVs in California, around these event dates of eligibility changes, the market share of EVs has been relatively flat. A period of growth in the EV share did occur after August 2022, when foreign made EVs *lost* eligibility to 30D tax credits. In the six months following the re-eligibilty of the two popular Tesla models (which were 100% produced in the US), data show no growth in the EV market share.

Quasi-Placebo Estimates for EVs Without Eligibility Changes

The event study graphs above compare outcomes of treated EVs to a control group of ICE vehicles. One potential concern could be that EVs and ICE vehicles have different trends in outcome variables (pricess and registrations). We did have no significant pre-trend differences for most outcomes and events, though prices appeared to be on a different trend for the January 2023 Included group. To investigate this possibility, this subsection swaps out the treated group with all other EVs in placebo event studies, though we keep the control group unchanged. These regressions are also of interest on their own as the tax credit eligibility chance could create competitive effects on other manufacturers.

The results appear in Figure **??** for prices and Figure **??** for registrations. Like estimates for the directly-affected EV manufacturers, these graphs show statistically insignificant effects. The data show some differences in trends between the directly and indirectly treated EV manufacturers. In particular, in line with the earlier discussion, prior to January 2023 Tesla appeared to be on a different trend of lowering prices more than other EV manufacturers. Recall that Tesla price declines remained on the same trend after the January 2023 inclusion in 30D tax credits. For other EVs, data do not show such an apparent pre-period difference in prices compared to ICE vehicles, but do show price declines thereafter. For registrations, it appears that in the August 2022 exclusion event, the other EV manufactures had sales growing more compared to ICE vehicles prior to the event than the treated group had, with insignificant differences thereafter.

3.3 Benchmarking Price and Registration Impacts

The previous subsections find that EV tax credits were completely passed through to consumers, but that these credits had no detectable impact on EV registrations. We now compare these

quantity estimates with magnitudes that we might expect on the basis of previous demand elasticity estimates. Berry, Levinsohn and Pakes (1995) estimate model-level own-price elasticities of 3.0 to 6.5, with more expensive vehicles more inelastic. Grieco, Murry, and Yurukoglu (2023) estimate an average model-level price elasticity of 5.4 for the year 2015, with richer consumers more inelastic. Armitage and Pinter (2022) estimate a mean elasticity of 2.2 for EVs. They comment that their estimated elasticity for non-EVs is less elastic than other estimates, so their EV elasticity may also be relatively low. Cole et al. (2021) choose 2.5 as the overall elasticity of EVs within a vehicle class.

We summarize these estimates from the literature as perhaps implying a demand elasticity for small groups of EV models in our setting of 2.5. The (weighted) mean credit-exclusive sale price of an EV model that became eligibile for tax credits in January 2023 was \$50,400. Therefore, the \$7,500 tax credit decreases net price by about 15% (≈\$7,500/\$50,400). Thus, if supply were fully elastic, we might expect credit eligibility to increase equilibrium quantity by $2.5 \times 15\% \approx 37.5\%$. Many of our estimates reject this magnitude

4 Explanations

Why do data show a muted short-run EV demand response to the 30D consumer tax credits? We discuss data available to evaluate several potential explanations: consumer income restrictions, supply constraints, a leasing loophole, and other explanations.

4.1 30D Consumer Income Restrictions

One possible explanation for why EV credit eligibility did not increase demand is that consumer incomes make consumers ineligible for credits, so we are mismeasuring eligibility. Recall that the 30D credits require buyers to have incomes below certain thresholds. To test this possibility, we use data on incomes of EV buyers slightly before the IRA, which proxy incomes of EV buyers under the IRA.

These tax credit data from year 2021 suggest that most EV buyers have incomes that qualify for the IRA EV tax credits. Non-qualifying incomes therefore likely do not explain the lack of clear quantity or price impacts. Appendix Figure A1 uses the IRS Statistics of Income data to find that about two-thirds of people who claimed the Clean Vehicle Credits in year 2021 had adjusted gross incomes under \$200,000 and thus would likely continue to qualify for the credits. That qualifying share has likely grown with the introduction of lower-priced EVs in 2021 and beyond. Furthermore, richer households are more likely to purchase more expensive EVs, but such vehicles are already excluded from the subsidy eligibility due to the MSRP price caps (55,000 USD for sedans, 80,000 USD for SUVs).

4.2 EV Supply Constraints

A second possible explanation for why EV tax credits may have had muted short-run impacts on EV registrations is that EV manufacturers faced sufficient supply chain constraints that they could not rapidly provide vehicles that consumers wanted to purchase.

Manufacturers can adjust a model's production to respond to changes in demand, and standard demand estimates assume that auto manufacturers produce at constant marginal cost. The coronavirus pandemic, however, disrupted supply chains. EV production may have been particularly constrained due to scarcity of battery parts, complex computer chips, and other inputs to these relatively new products.

Figure 7 presents inventory trends over time. Panel (a) presents average days-to-turn for EVs (excluding Tesla, which as discussed earlier, does not report days-to-turn) and non-EVs. Days-to-turn is a common industry metric describing the number of days a vehicle sits on a dealer's lot before it is sold. Low values of this metric therefore represent supply chain constraints. At the beginning of our sample period, the mean EV sold in October 2021 spent 48 days on the lot before being sold. This dropped to 19 days by August 2022, illustrating substantial supply constraints. In the second half of our sample period, however, days-to-turn steadily increased. By August 2023, days-to-turn exceeded two months.

Although our days-to-turn data exclude Tesla, the largest US EV manufacturer, Panel (b) of Figure 7 presents estimated wait times reported on the Tesla website, which tell a qualitatively similar story to Panel (a). Wait times peaked in mid-2022 in the range of 100–350 days, depending on the model, before dropping steadily over the next 12 months. Wait times were low for the Tesla Model 3 in January 2023 and in the following months, and typically within 1 to 2 months for the Tesla Model Y.

Our overall assessment is that EV supply was improving but might have been inelastic in August 2022. Quantities could adjust more flexibly in response to the January and April 2023 eligibility changes. Supply chain shortages are therefore unlikely to explain the limited demand response we observe to EV credits.

4.3 Leasing Loophole

In January 2023, the Treasury Department let all EV qualify for credits under 45W. Can this reform explain why the 30D EV credits had muted estimated effects on EV quantities? The availability of this leasing loophole effectively means that all EVs can qualify for tax credits if they are leased, even if all EV's domestic content, pricing, or consumer income make the transaction ineligible for 30D credits.

Panel (b) of Figure A3 shows the share of vehicles that are leased in California. The solid line shows EVs while the dashed line shows IC vehicles. The vertical dashed lines show the 3 eligibility changes we study.

This figure reveals an enormous increase in leasing for EVs after January 2023. We do not

observe such a substantial increase in leasing for ICE vehicles.[9]

Figure A3 (b) shows a similar graph, but separately by manufacturer. This figure shows that manufacturers with some sub-models eligible for 30D credits and others ineligible have large increases in leasing. This includes Volvo, Volkswagen, Jeep, BMW, Hyundai, and Kia. Manufactures with little increase in leasing include Tesla and Chevrolet. These time series trends are in line with findings based on data from Edmunds that illustrate an increase in the lease share for EV models supplied by Korean and European manufacturers for January 2023 onwards (Bound 2023). Of course, for a component of the IRA which some policymakers intended to encourage domestic EV manufacturing, it is noteworthy that this leasing loophole appears to encourage sales for foreign manufacturers.

Figure 8 separates this leasing rate time series by eligibility groups for the 30D tax credits. The interesting question here is whether manufacturers which were ineligible for the 30D credits became more likely to increase leasing under 45X.

An important pattern in Figure 8 is that the group of vehicles which lost eligibility for EV tax credits in August 2022 became more likely to increase leasing in January 2023. This makes sense because it illustrates leasing as a response to the loss of 30D EV tax credits. If consumers could not obtain a $7500 tax credit by buying these EVs, they instead obtained a tax credit by leasing them. The group of vehicles which gain eligibility in January 2023, primarily Tesla, does not experience a dramatic change in leasing when the lease credits become available, which makes sense. A group of manufacturers which lost eligibility for EV purchase credits in April 2023 had an increase in the share of vehicles that are leased in later months. The graph also shows that ICE vehicles, both luxury and non-luxury, had flat trends in lease shares over this period. This is despite luxury ICE vehicles having a higher baseline lease share than their non-luxury counterparts.

An informative way to boil down this data is to show how the leasing loophole affects lease rates for vehicles not eligible for the 30D credit as of January 2023 because such vehicles failed to meet either the North American final assembly requirement or the price requirement. We compare against a control group of ICE vehicles. We again use equation (1) to estimate the effects.

Figure 9 shows the resulting event steady graph for leasing rates. The leasing loophole increased EV leasing rates by 20 percentage points. Excluding Tesla vehicles, this effect exceeds 25 percentage points. Given baseline leasing rates of around 20 percent, these estimates imply that the 45W leasing loophole increased leasing rates by over a 100 percent relative to baseline levels.

The IRA's EV credits initially sought to encourage domestic sourcing and excluding some vehicles from the 30D credits sought to ensure that goal. Why does the previous section find that such exclusions had limited effects on consumer EV purchases? The explanations earlier in this section do not substantially account for our finding of muted impacts on EV quantities. We believe the leasing loophole provides an important explanation. Losing eligibility for the EV purchase tax credit has limited effects on EV purchases when buyers can substitute to leasing. We conclude the leasing loophole accounts for an important share of our previous section's conclusions that EV

[9] July 2023 shows a one month drop in releasing which we believe reflects a data blip.

purchase tax credits have limited effects on EV purchase quantities.

We note two other important observations about this leasing loophole. First, leasing is not costless for consumers. Some consumers prefer to purchase. For this reason, even with the leasing incentive in 45W, less than 100% of consumers choose to lease vehicles. We revisit this in the next section to estimate welfare consequences of these subsidies.

Second and related, under this policy, consumers who wanted to receive the credits and were not eligible for 30D still have to lease a vehicle for the full lease period. Our research discovered that just as 45W provides a loophole to allow leasing to circumvent purchase constraints, some dealers further avoided 45W requirements by using a financing loophole that lets them avoid the full leasing requirements and still receive the EV tax credits.

Specifically many dealers described to us the practice of encouraging consumers to sign a lease contract, and then after a very short time, buy out the lease contract and end up with a vehicle purchase. We are not aware of previous evidence in any source, including media outlets, describing this loophole within a loophole (the lease buyout loophole to avoids prolongued 45W leasing requirements, which avoid the 30D domestic content, price and income requirements)

This double-loophole operates as follows. Consider a vehicle excluded from 30D credit eligibility either due to domestic sourcing requirements or a high MSRP. Equivalently, consider a purchase where the consumer's income exceeds the IRA thresholds. Acquiring such a vehicle would only receive IRA tax credits if the consumer leased the vehicle. Depending on leasing contract details, however, if the consumer bought out the lease within a few months of initiating the lease, the consumer could receive the $7500 45W credit despite owning the vehicle. Direct conversations with sales representatives from almost all major EV manufacturers (including Jeep, Volkswagen, Hyundai, Volvo, Nissan, Mercecdes-Benz, and Audi) indicated that dealers were both aware of this possibility and, in some cases, encouraged it, suggesting that the strategy could result in savings of thousands of dollars.

Despite this anecdotal evidence and theoretical possibility, the limited available evidence suggests that such a practice is not widespread. One pirce of preliminary evidence is from Texas registration data. Unlike in the California registration data used for most of this paper's analysis, the Texas registration data has complete VINs, allowing us to track registrations of the same vehicle across time. Using other data from Cox Automotive, which associates a VIN to transaction-level details including whether the vehicle is leased or purchased, we can consider only the subset of registrations in Texas which are identified as leased by Cox. Due to limitations in Cox's coverage, these data substantially under-represent Tesla vehicles, and may not be otherwise representative of the overall market (for EVs or otherwise). With that understanding, we consider new leases initiated in the second half of 2022 and the first half of 2023. We then see which of these leased vehicles are associated with re-registration to a different address within three months in the Texas data.

Considering such cases as early buyouts, we find that ICE leases had an early buyout rate of less than 1% for both time periods. On the other hand, the corresponding rate for EVs increased

from approximately 0.4% to 1.4% from the second half of 2022 to early 2023. This potentially represents some change in behavior among EV buyers, though the overall count of Texas EV leases for early 2023 (as recorded in Cox data) is only 1,811, and so this rate represents only 25 lease buyouts. This value would likely be even smaller if we had access to the universe of leases, as Tesla (essentially not included in this sample) does not allow for lease buyouts..

4.4 Other Considerations

While we believe that the previous subsections describe the most likely explanations for the limited change we observe in registrations, they are not exhaustive. Demand may be more inelastic than in previous estimates. Additionally, we estimate a short-run response, while the papers above identify longer-run elasticities. Furthermore, consumers may be confused about which models are eligible, especially on a month-to-month basis. Finally, the tax credits may not not fully salient because they cannot be claimed until taxes are paid in the calendar year after purchase. This final theory is supported by evidence from earlier clean vehicle incentive policies; for example, Kim (2023) finds that consumers are roughly three to four times more responsive to EV incetives when structured as rebates rather than tax credits. The policy changes in January 2024, which allow consumers to elect to recieve their 30D credits at point-of-sale, may alleviate this concern.

5 Discussion

The IRA was created as a climate bill and as an industrial policy responding in part to the rapid growth of EVs in China. This paper analyzes short-term effects of EV tax credits, especially their "Buy American" restrictions.

In aggregate, although we analyze a massive policy, we fail to detect substantial short-run effects on EV sale prices, which implies that the EV credits were largely passed through to consumers as claimed on the subsequent income taxes. We also fail to detect substantial impacts on EV sale quantities. At the same time, we find that an alternative commercial vehicle credit, which the US Treasury later interpreted to allow leasing, led to enormous increases in lease rates

What do these findings indicate about the IRA's success in achieving oits short-run goals? Such conclusions of course depend on the law's goals, which vary among its suporters. West Virginia Senator Joe Manchin described, "...[T]he purpose of the law which is to bring manufacturing back to America and ensure we have reliable and secure supply chains." For this reason, he described the Treasury Department's interpretations of the IRA, including allowing credits for leased vehicles, as "horrific',' "pathetic," and "dangerous," among other colorful language (Shepardson 2023b; Manchin 2023), and has threated to sue or repeal the IRA over other such Treasury interpretations (Shepardson 2023a).

The Biden Administration may describe additional objectives. Allowing leased vehicles to receive EV credits may have helped placate allies in South Korea and Europe who wanted their manufacturers to qualify for the credits (Shepardson 2023b , https://www.eenews.net/articles/treasury-

omits-leased-evs-from-made-in-america-mandate/). Additionally, environmental interest groups wanted to accelerate EV adoption, and expanding eligibility for credits could support that objective.

One broad way to learn about what our conclusions mean for these broad goals is to examine time series trends for the entire EV market. Figure 2 shows that while EV market share in California and nationwide is higher now than it was in late 2021, there has been little movement since the passage of the IRA. This fact, in concert with the lack of a meaningful increase in the proportion of EVs assembled in the United States (see Figure 3), suggests that the substantial expense of the IRA EV credits in the short run has not substantially transformed the US EV market. The presence of further subsidies (including provisions which subsidize domestic battery production) and sticks (including escalating requirements for vehicles to maintain 30D eligibility) may produce medium- and long-run impacts.

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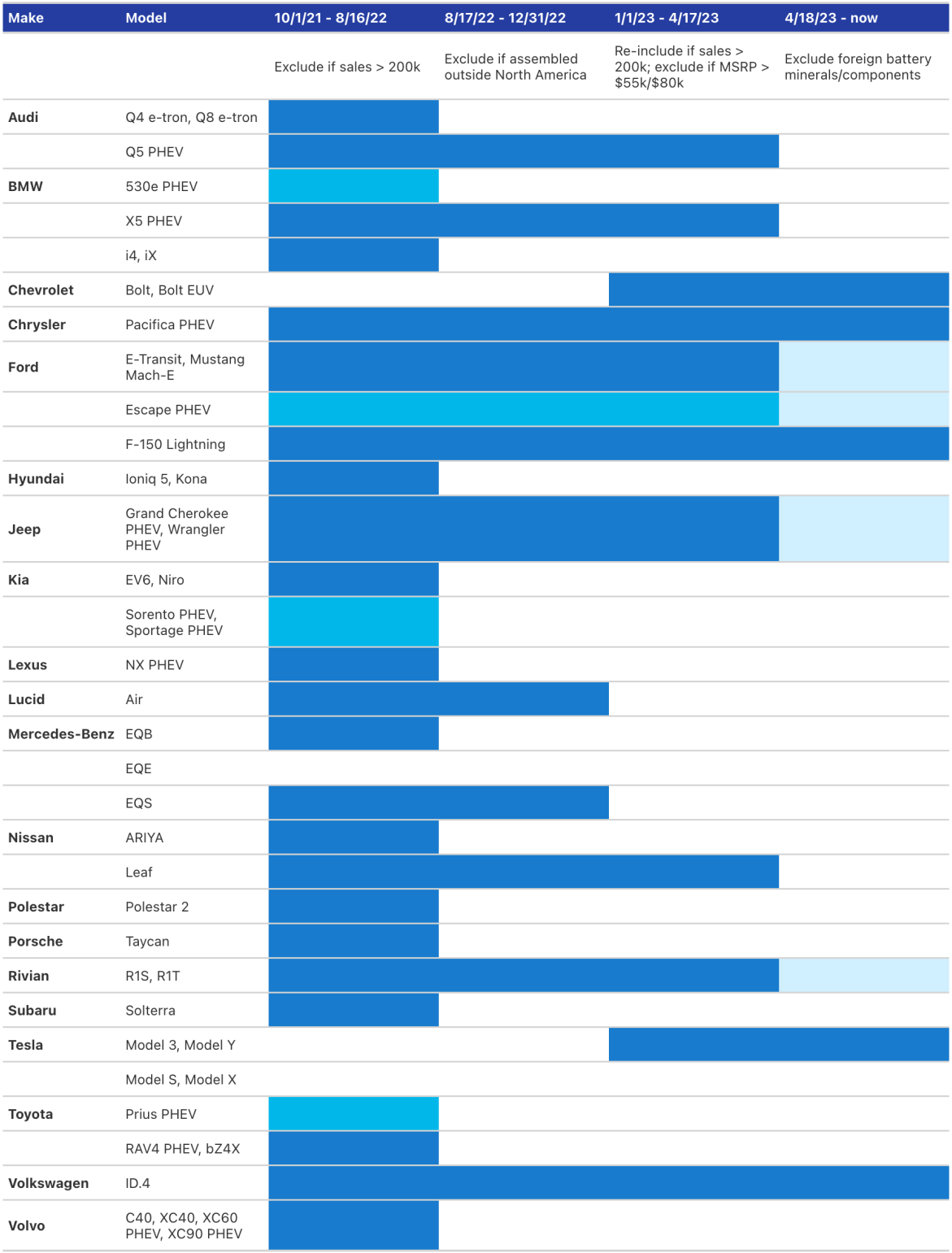
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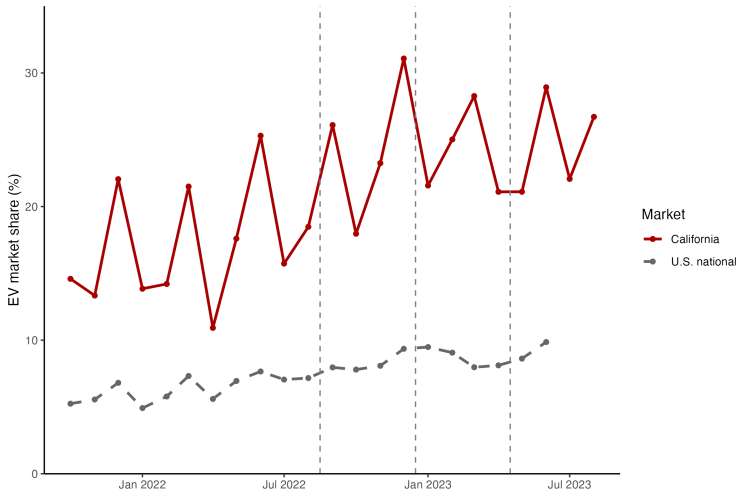
Figure 1: **Section 30D New Clean Vehicle Credit Eligibility by Model Over Time**



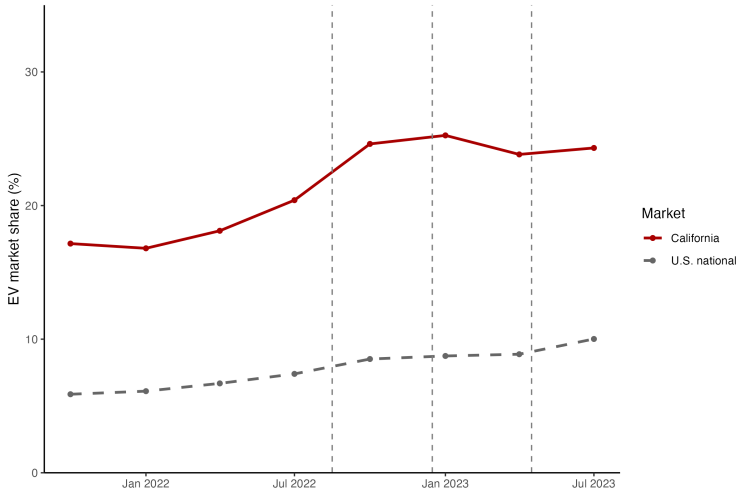
Notes: This figure shows which popular models are available for the IRA Section 30D Clean Vehicle Credits by time period.The color intensity indicates the credit amount that the vehicle is eligible for: full shade indicates the full credit of $7,500, medium shade indicates credits from $3,750 to $7,500, and light shade indicates credits of $3,750. The figure excludes some less-popular models. The style and organization of this table followBuckberg (2023)'s Figure 3.

Figure 2: **EV Market Shares, California and National**

(a) **Electric Vehicle Market Share, Monthly**



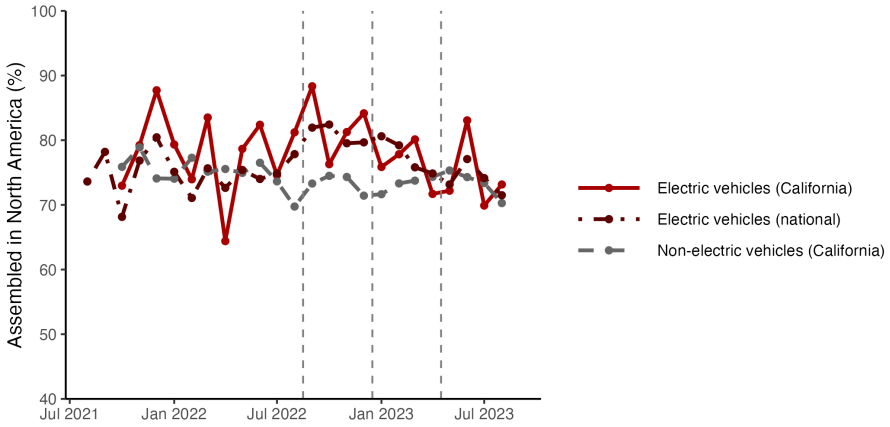
(b) **Electric Vehicle Market Share, Quarterly**



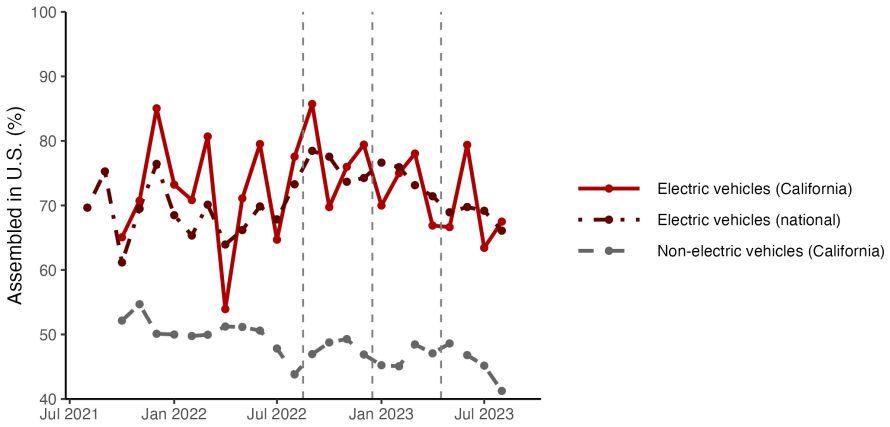
Notes: Panel (a) shows electric vehicle market share over time at the monthly level, while panel (b) shows the same data aggregated to the quarterly level. Values for the California market are derived from California registration data; values for the national EV market are from EV-Volumes; values for the national ICE market are from Edmunds.

Figure 3: **EVs, Share Assembled in North America and the U.S.**

(a) **Share Assembled in North America**

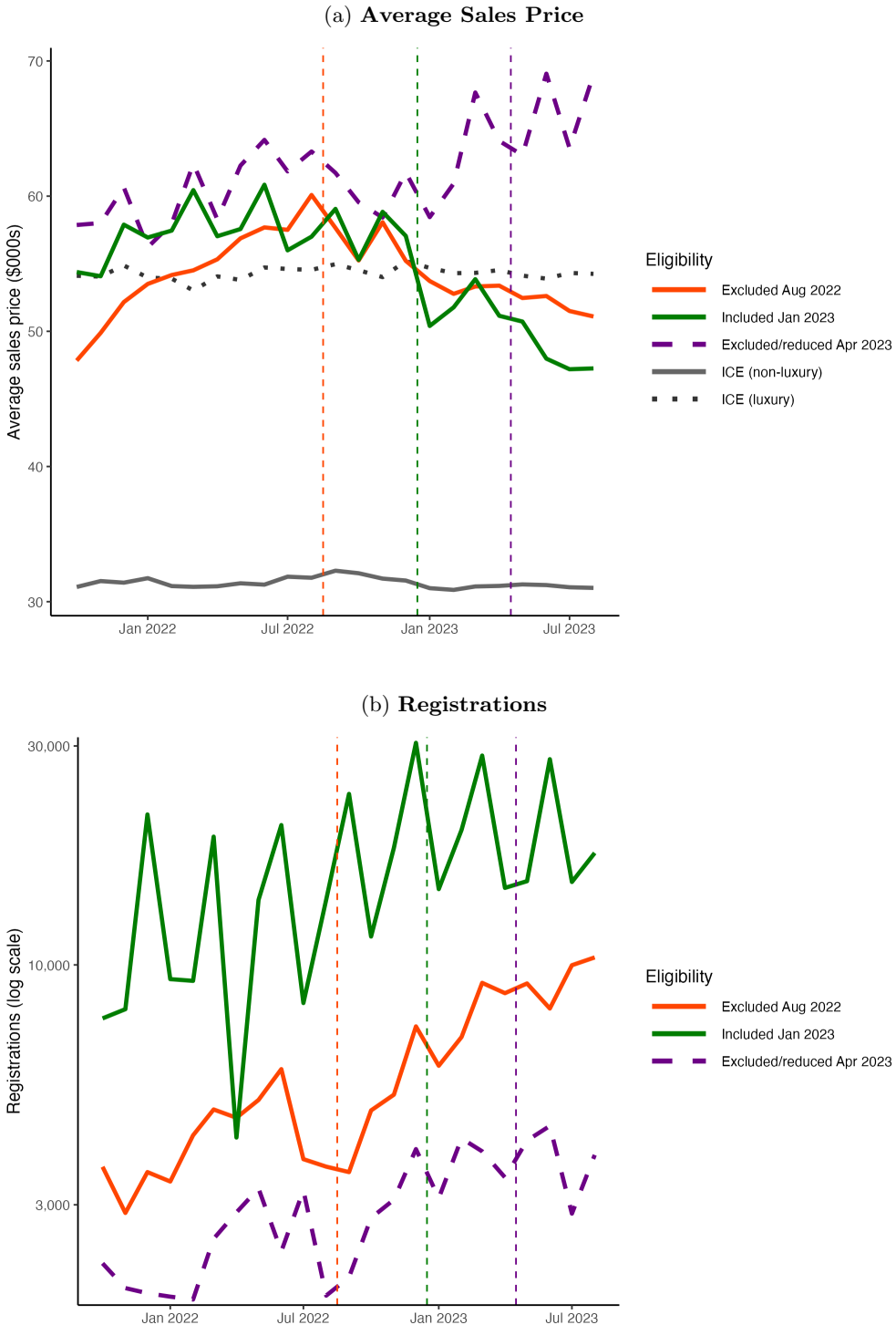


(b) **Share Assembled in the U.S.**



Notes: Panel (a) and (b) show the share of vehicles assembled in North America and the United States, respectively. Values for the California market are derived from California registration data and values for the national EV market are from EV-Volumes.

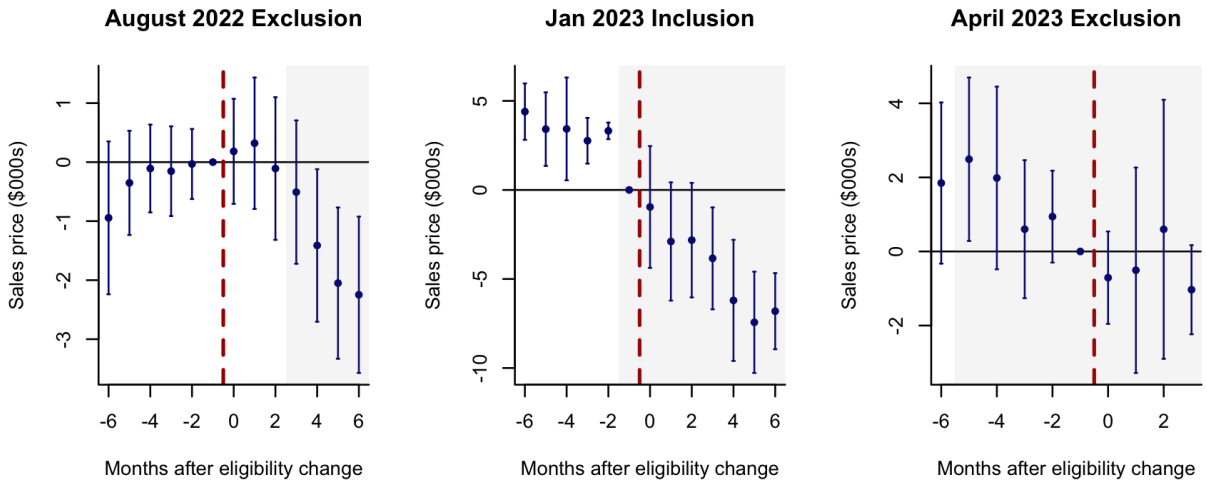
Figure 4: **California Average Sales Price and Registrations by Eligibility Group**



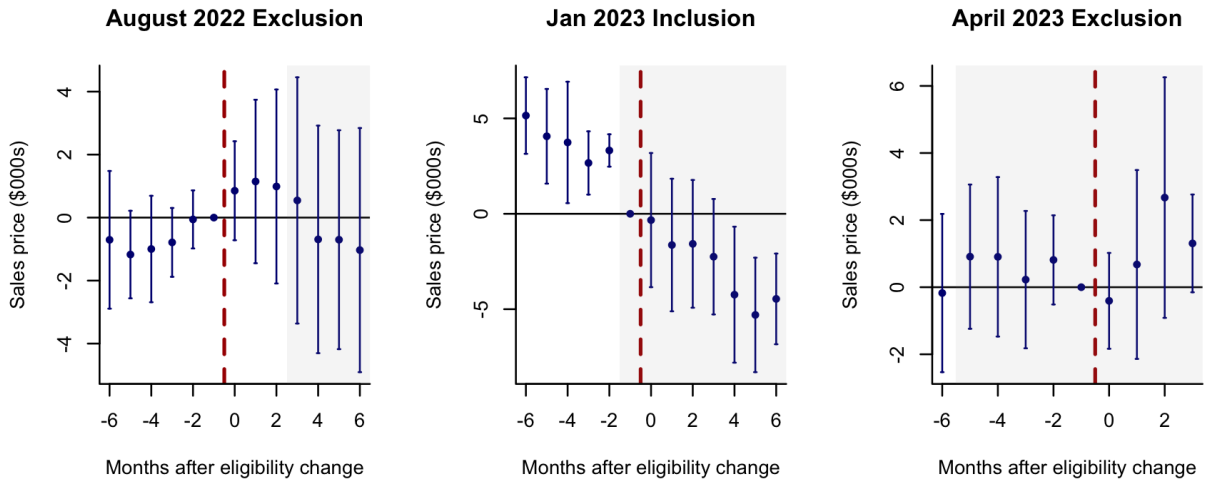
Notes: This figure presents, in panel (a), monthly average prices and, in panel (b), registrations in California for vehicles in each eligibility group. Eligibility groups are described in detail in Section 1.2.

Figure 5: **California Price Event Study**

(a) **By Eligibility Group, ICE Controls**



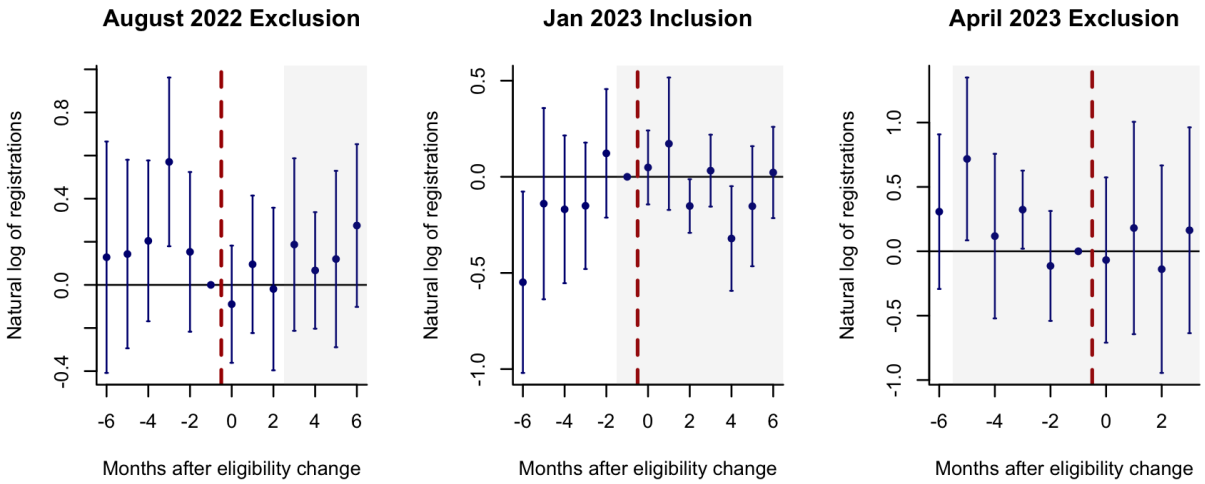
(b) **By Eligibility Group, EV Controls**



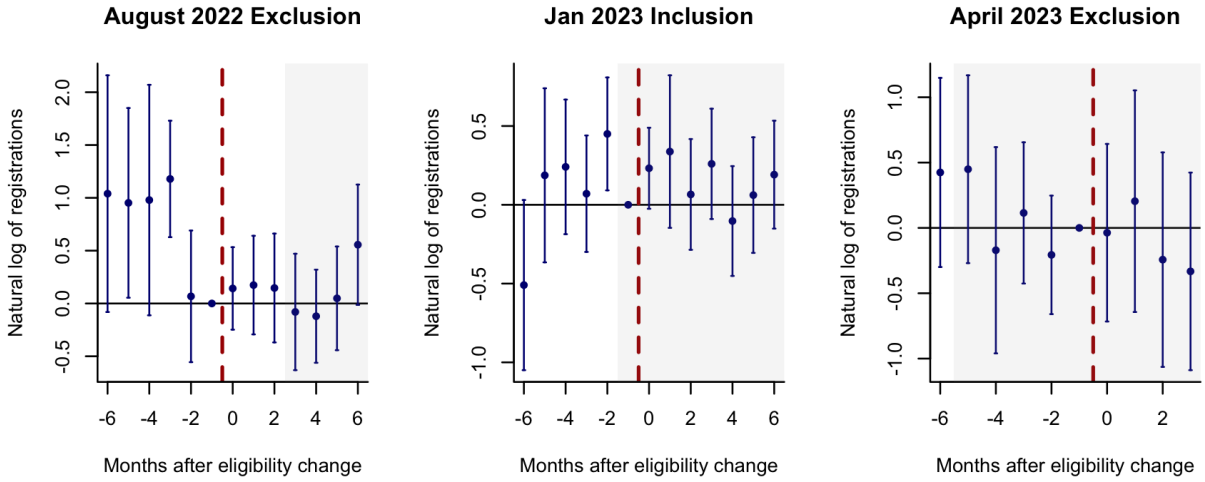
Notes: Panel (a) presents estimates of the relationship between eligibility changes and average sales price using equation (1) for each of the three considered eligibility groups, with ICE vehicles acting as the control group. Panel (b) presents estimates using the same equation, but using EVs outside of the eligibility group as the control group; Tesla vehicles are excluded from all control groups. Standard errors are clustered at the model level.

Figure 6: **California Registration Event Study**

(a) **By Eligibility Group, ICE Controls**



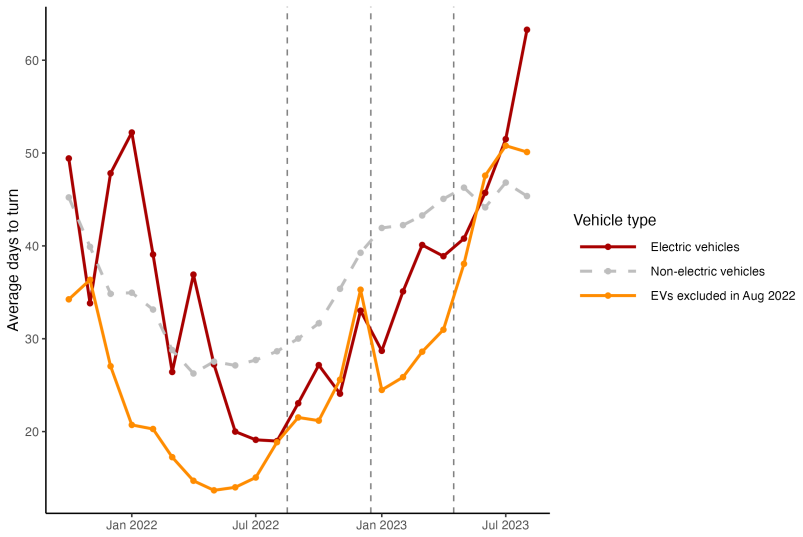
(b) **By Eligibility Group, EV Controls**



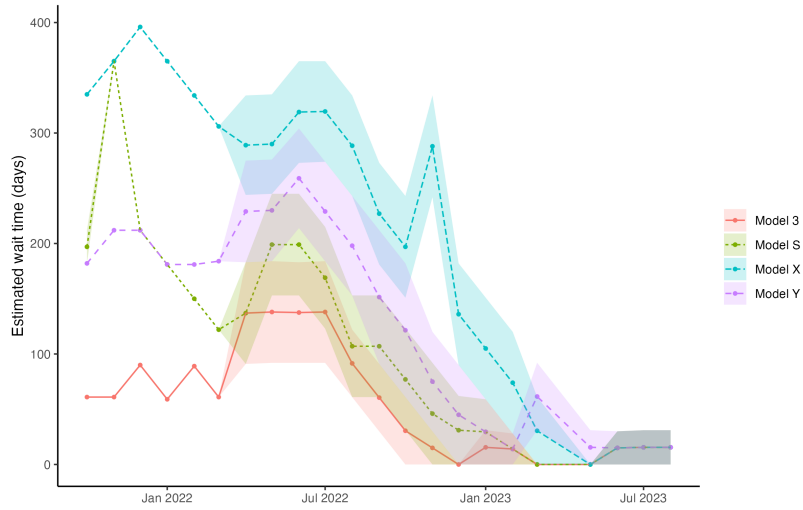
Notes: Panel (a) presents estimates of the relationship between eligibility changes and registrations using equation (1) for each of the three considered eligibility groups. Panel (b) presents estimates using the same equation , but using EVs outside of the eligibility group as the control group; Tesla vehicles are excluded from all control groups. Standard errors are clustered at the model level.

Figure 7: **Inventory Trends**

(a) **Days-to-Turn (Excluding Tesla)**

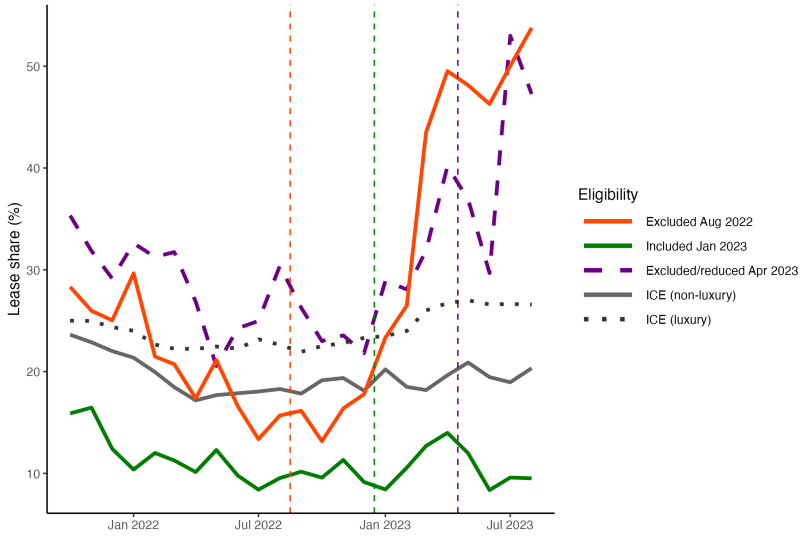


(b) **Tesla Wait Times**



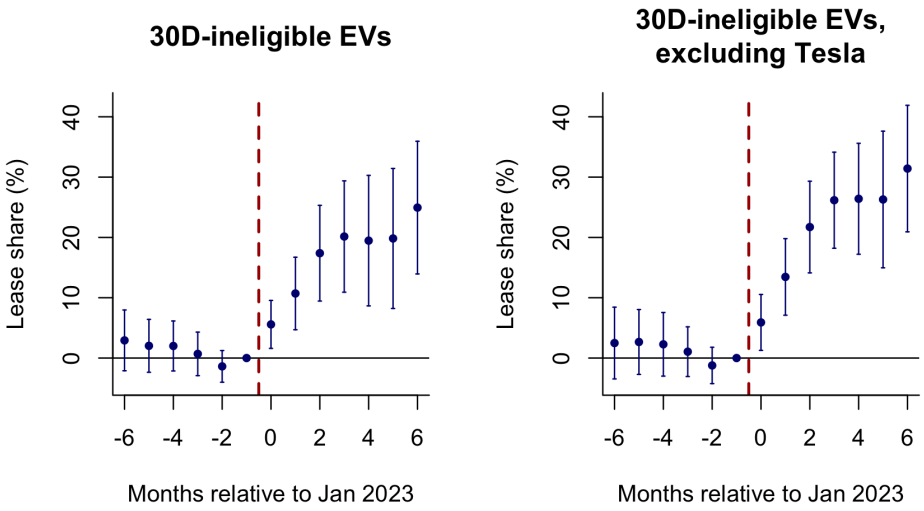
Notes: Panel (a) presents average days-to-turn for EVs and non-EVs sold in each month, using data from Edmunds; these data exclude Tesla. The *EVs excluded in Aug 2022* series plots the average days-to-turn for vehicles in this eligibility group, all of which are also included in the overall *Electric vehicles* series. Panel (b) presents estimated wait time for Teslas ordered in each month, as reported on the Tesla website. Starting in early 2022, the Tesla website reports a wait time interval, so we highlight that interval with dots at the midpoint.

Figure 8: **California Lease Shares by Eligibility Group**



Notes: This figure presents monthly lease shares in California for all vehicles in each eligibility group. Eligibility groups are described in Section 1.2.

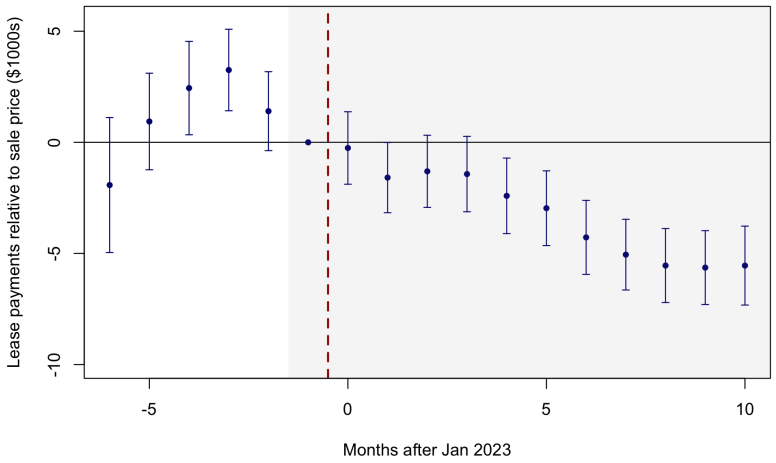
Figure 9: **California Lease Share Event Study**



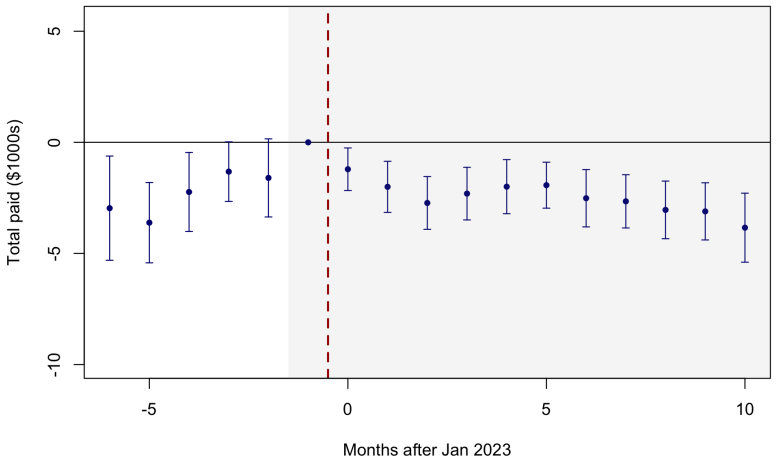
Notes: This figure presents estimates of the association between eligibility changes and lease shares using equation (1).

Figure 10: **National Total Lease Payments Event Study**

(a) **EVs not eligible for 30D in Jan 2023**



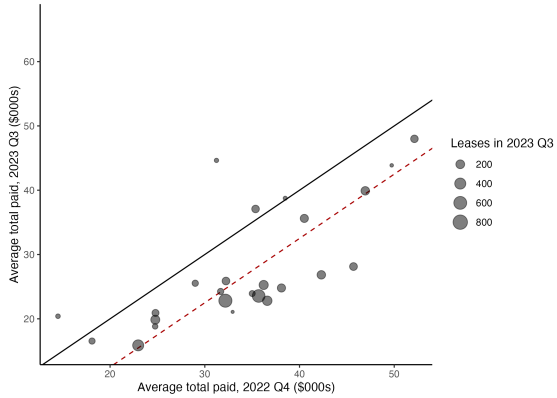
(b) **EVs eligible for 30D in Jan 2023**



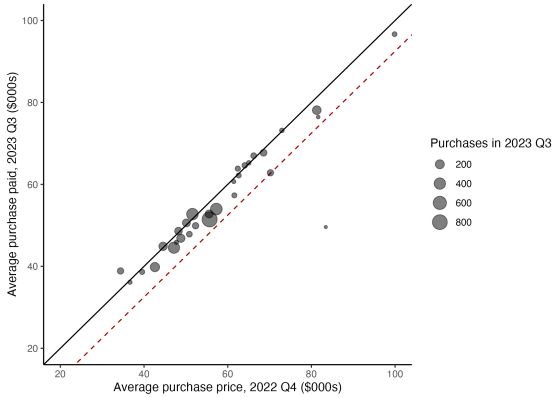
Notes: Panels (a) and (b) show event studies for their resepective portion of the EV market, with the outcome variable defined as the sum of down payment and all monthly payments in the lease agreement minus 0.45 times the corresponding monthly submodel sales price. The analysis is restricted to only 36-month leases, which account for over two-thirds of leases. All regressions are at the transaction level, include submodel and time fixed effects, and standard errors are clustered at the submodel level.

Figure 11: **Cox Total Lease Model-level Comparisons**

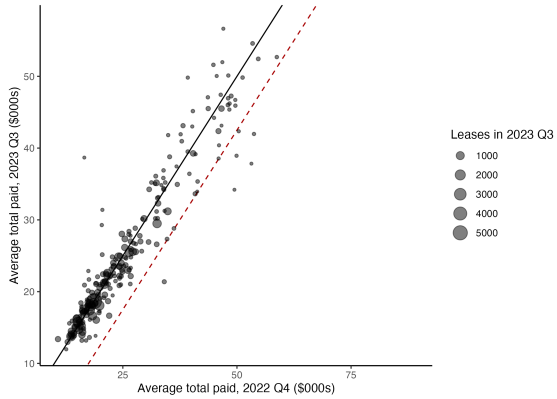
(a) **EVs not eligible for 30D in Jan 2023 (Total lease payments)**



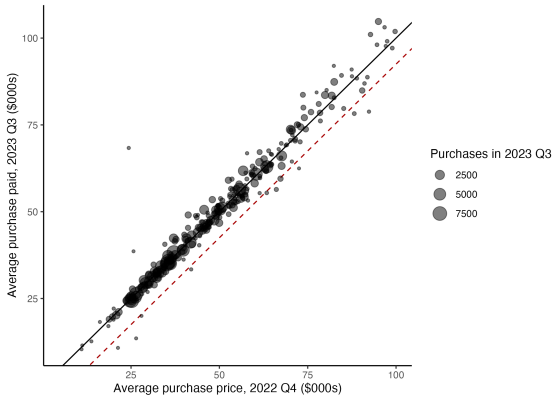
(b) **EVs not eligible for 30D in Jan 2023 (Sales price)**



(c) **ICE vehicles (Total lease payments)**



(d) **ICE vehicles (Sales price)**



Notes: This figure shows the change in lease and purchase prices for different groups of vehicles between the fourth quarter of 2022 and the third quarter of 2023. Prices are aggregated to the model level. We use only 36-month leases for computing the lease prices, and exclude Tesla from the analysis. The solid black line in each figure is the 45 degree line, and the dashed red line represents a $7,500 reduction in price (analogous to full passthrough of the 45W credit in the case of lease prices, assuming no other price trends).

Online Appendix

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

Hunt Allcott
Joseph S. Shapiro
Felix Tintelnot

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A Data

We have two administrative datasets from the California Department of Motor Vehicles (DMV): they are both cross-sectional vehicle-level registration records, as of October 2022 and July 2023. For each observation, we observe characteristics of each vehicle. The characteristics include prefix of vehicle identification number (VIN), self-reported price, vehicle make, series, model, model year, date of the most recent registration, odometer reading and reading date, year-month of each ownership transfer, indicator of leased vehicle, type of license. The VIN prefix is the first to the eleventh digits of the VIN, excluding the ninth security check digit.

We first approximate the initial registration date of each observation based on the given last registration date, and odometer reading and reading date. We begin by checking the odometer reading; if the reading is below or equal to 250 miles, we approximate the initial registration date with the odometer reading date. For observations with missing odometer reading information or odometer reading larger than 250 miles, we proceed to match the last registration date and model year. We define the plausible window of sales for each model year to be from July 1st of the previous calendar year to April 1st of the following year: if the last registration date falls in this window, the most recent registration is assumed to be the vehicle's initial registration and we approximate its initial registration date with the last registration date. Most of the initial registration dates ($\sim$96%) are imputed by odometer reading date. Given the regulation of annual registration in California, we assume the approximation of initial registration date by last registration date to be accurate for vehicles aging 1 year or less.

With the approximate initial registration date, we check the trend of the count of daily new registration overtime based on two cross-sections. We find roughly 45 days delay for all registration to appear in the DMV record. Given the possibility that later registrations overwrite earlier ones, we use the earlier cross-section to approximate the initial registration date of earlier vehicles for accuracy. we construct the imputed dataset by combining the observations from the October 2022 cross-section with approximated initial registration starting from October 1st, 2021 and before August 15th, 2022 and observations from the July 2023 cross-section with approximated initial registration later August 15th, 2022 (including) and before May 1st, 2023.

With the VIN decoder from National Highway Traffic Safety Administration (NHTSA), We decode the unique VIN prefix observed in the cross-sections to recover the production and assembly location, vehicle type, and powertrain type.

Merging the imputed dataset with the NHTSA VIN decoder, we produce panel A: registration-level data, where we observe VIN prefix, self-reported initial sales price, indicator of leased vehicle, production and assembly location, and powertrain type.

The other primary data source we use, both for the US-wide and international comparisons, is from EV-Volumes. EV-Volumes collects and maintains data on sales of electric vehicles at the monthly and model level across over 100 markets. From this dataset, we are able to recover the within-EVs market share of individual models in addition to making comparisons across countries. The data itself requires minimal processing before use, with the key steps being the manual con-

struction of crosswalks with the California DMV data and the Department of Energy eligibility data, both at the model level. The sales data is meant to be interpreted as delivered vehicles, and so the timing of these data should align closely with the California DMV data. EV-Volumes updates their data on a monthly basis, and these updates come with retroactive revisions to the prior months data.

In both panel, our scope of observation is light-duty vehicles defined by a gross vehicle weight rating of 10,000 lbs. or less.

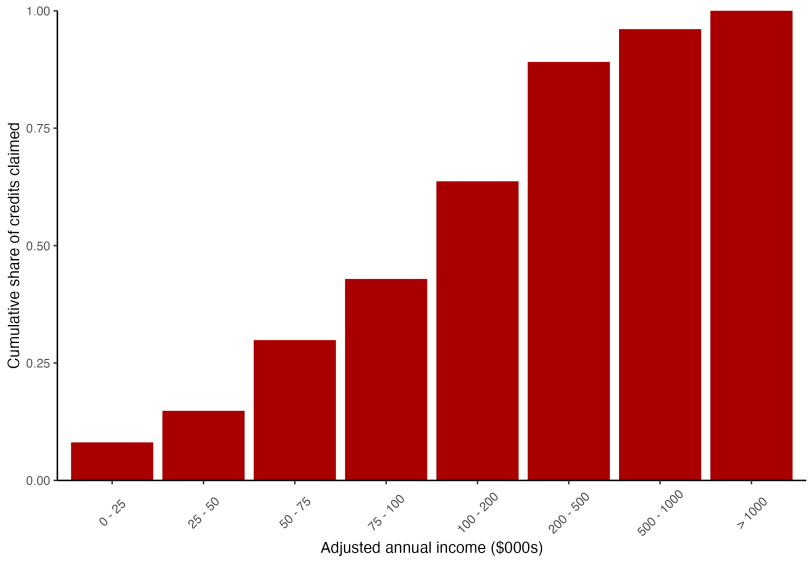
Summary statistics for the resulting cleaned panel can be found in Table A1. We also provide sales price and registraion trends for the best-selling 10 EV models in our panel in Figure A2. Two key facts which are immediately apparent from these figures are 1) that Tesla vehicles (especially the Models 3 and Y) are decisive market leaders, and that 2) many of the best-selling EVs have experienced gradual price declines over the past twelve months, a pattern which persists across 30D eligibility categories.

B Descriptive Analysis

This section includes a collections of descriptions of the core data used throughout the main text, in addition to data which support the broader institutional framework in which our main results are situated. We provide suggestive evidence for the income distribution of electric vehicle purchasers in Figure A1, which shows the income distribution for taxpayers who claimed the clean vehicle credit in 2021. Note that these values are for *tax year* 2021, meaning they represent credits for vehicles purchased in 2020. One side effect of this is the omission of Tesla buyers from consideration, as Teslas were inelgible for the credit throughout all of 2020. Nonetheless, these data suggest that a substantial upwards shift in EV buyers' income would have had to taken place between 2020 and 2023 for the IRA's income constraints (e.g. $225,000 for heads of households) to have a substantial aggregate effect.

In Table A1, we provide summary statistics for key coavariates in the California registration data (Panel (a)) as well as national data, provided by EV-Volumes and Edmunds (Panel (b)). We also show the model-level time trends in prices and registrations for the best-selling 10 EV models in Figure A2. (Note that the most expensive of the 10, the Tesla Model X, is omitted from Figure A2a due to its price being consistently censored in the California data.)

Figure A1: **Cumulative Density Function of Income for Taxpayers Claiming Clean Vehicle Credit in 2021**



Notes: This histogram shows the cumulative distribution of adjusted gross income for taxpayers claiming the Clean Vehicle Credits in 2021, for electric vehicle purchases made in calendar year 2020.. Data are from the IRS Statistics of Income (2023).

Table A1: **Summary Statistics**

Panel (a): Submodel-by-Month California Data

	Mean	Std. dev.	Min.	Max.	Obs.
Registrations	125	420	1	19,012	23,514
Sale price ($000s)	53.2	21.1	0.3	96.7	22,914
Lease price ($000s)	52.5	21.0	0.0	96.7	20,179
Percent leased	25.0	22.6	0	100	23,514
EV	0.11	0.31	0	1	23,514

Panel (b): Model-by-Month US Data

	Mean	Std. dev.	Min.	Max.	Obs.
Sales (000s)	0.97	3.27	0	34.90	2,102
Percent leased	21.6	16.1	0	100.0	7,529
Days to turn	35	36	1	355	7,919

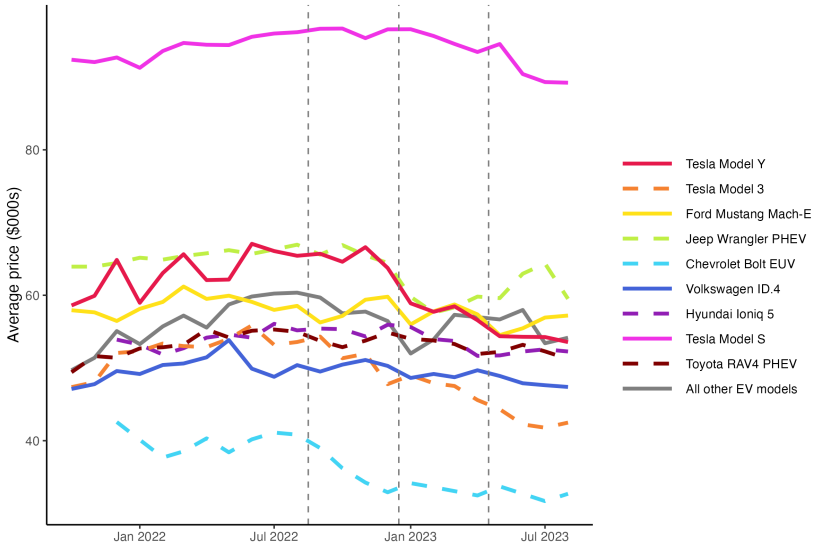
Panel (C): Submodel-by-Month US Cox Data

	Mean	Std. dev.	Min.	Max.	Obs.
Percent leased	19.1	22.9	0	100.0	30,945
Sale price ($000s)	64.3	54.3	0.0	817.3	30,055
Lease price ($000s)	62.1	44.8	9.5	716.6	22,065
Lease term (months)	37.1	4.7	1.0	72.0	20,177
Lease down payment ($000s)	0.0	0.0	0.0	0.2	14,594
Lease monthly payment ($000s)	1.0	1.5	0.0	83.3	19,386
EV	0.23	0.42	0	1	30,945

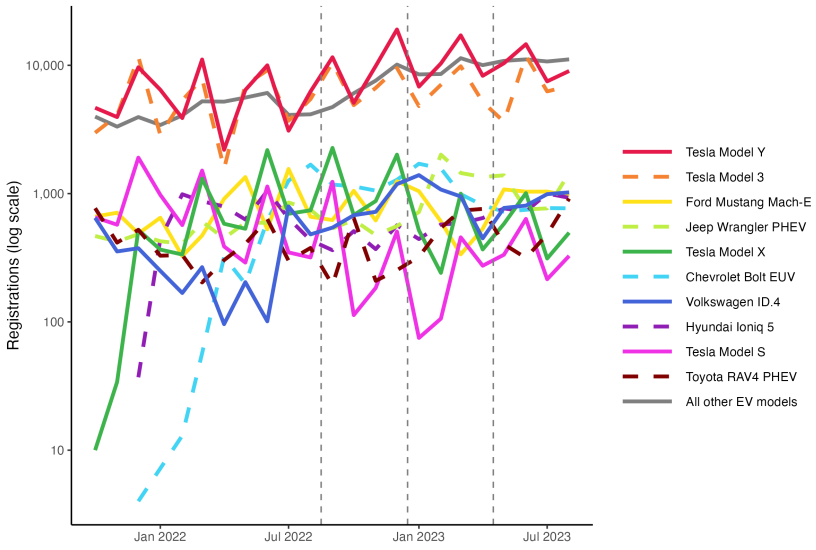
Notes: This table presents summary statistics for the period Oct 2021 - August 2023. Panel (a) presents the California DMV data for both EV and combustion engine vehicles. Panel (b) presents national data for electric vehicles from EV Volumes, and the lease share and Days to Turn are from Edmunds for both EVs and combustion engine vehicles.

Figure A2: **Registration and Price Trends for Top-10 EV Models in California**

(a) **Sales Prices**



(b) **Registrations**



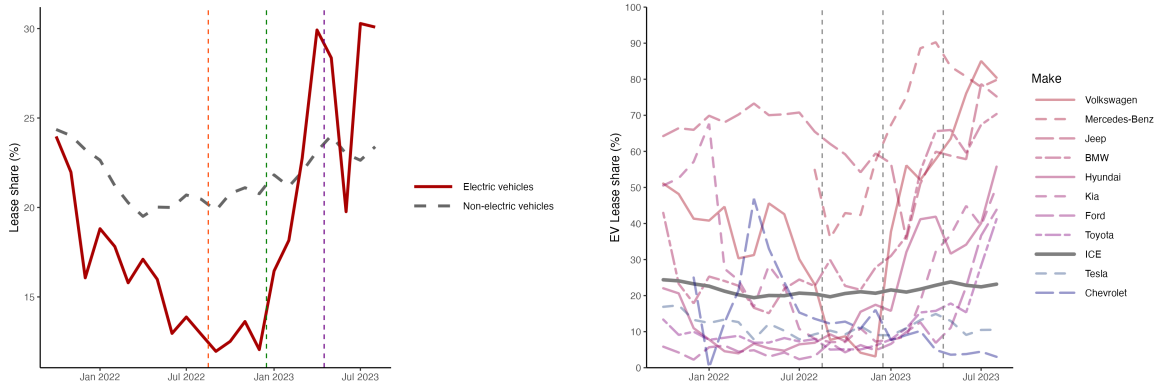
Notes: Based on registration data from California, panels (a) and (b) show the monthly registration counts and monthly average sales prices for the 10 EV models with the most registrations in our sample period (August 2021 to August 2023). Note that the Tesla Model X is excluded from panel (a) due to its high price being consistently censored in the California data; see Section 2 for details on the data cleaning procedure.

Finally, we also provide alternate visualizations of the differential trends in lease share between EVs and non-EVs around the time of the IRA's passage; the following figures complement Figure

8. First, we consider the aggregate market trends in Figure A3a, which shows the trends in lease shares among all EVs and non-EVs. Then, breaking down EVs by make, we see in Figure A3b that almost all of the best-selling EV makes experienced substantial rises in their lease share after the 45W lease credit changes were announced at the end of 2022. The only notable exceptions appear to be Tesla (who is known to have an idiosyncratic relationship with leasing) and Chevrolet.

Figure A3: **California Lease Share Trends**

(a) **EVs vs. Non-EVs** (b) **Registrations**



Notes: Panel (a) presents trends in lease share between all EVs and non-EVs in California around the time of the IRA's passage. Panel (b) presents California electric vehicle lease shares by make for the 10 makes with the highest sales of EVs in the California registration panel, compared against all non-EVs. The *High leasing group* is defined as having a lease share in August of 2023 larger than the the average for ICE vehicles, and the *Low leasing group* as the remaining EVs. All series other than *ICE* are computed as the ratio of leases to registrations for all of the make's EVs.

C Credit Eligibility details

Throughout the main text, and particularly in Section 1.2, we elide some details of eligibility for the Clean Vehicle Credits which are secondary to our analysis. Most prominently, in addition to the three largest groups which experienced eligibility changes, there are two groups who experienced no change and one more which lost eligibility. These three additional groups are listed below as items 4-6, complementing the first three groups which were discussed previously.

(1) **Excluded Aug 2022**. This groups is comprised of models that lost eligibility for tax credits on August 17, 2022. These submodels originally had eligibility through the Energy Policy Act of 2005 and the American Recovery and Reinvestment Act of 2009. These submodels become ineligible because they are assembled outside of North America. This group includes some Audi, BMW, Mercedes, and Nissan models, and all Hyundai, Kia, Lexus, Polestar, Porsche, Subaru, Toyota, and Volvo models.

(2) **Included Jan 2023**. This groups is comprised of models that were ineligible before January 1, 2023 under the American Recovery and Reinvestment Act of 2009 credit. They became eligible because of the removal of the manufacturer-level 200,000-vehicle limit. This group includes the Chevrolet Bolt and the Tesla Models 3 and Y.

(3) **Excluded Apr 2023**. This groups is comprised of models that were eligible before April 18, 2023 but lost part or all of the credits due to battery sourcing requirements. This includes some Audi, Ford, and Nissan models and all Rivian models.

(4) **Excluded Jan 2023**. This groups is comprised of models that were eligible before January 1, 2023. They became ineligible because their price exceeds the MSRP cap. This group includes Lucid and the Mercedes EQS.

(5) **Always included.** This groups is comprised of models that were cotinuously eligible throughout our October 2021 through August 2023 sample. This includes all Chrysler and Volkswagen models.

(6) **Always excluded**. This groups is comprised of models that were never eligible between October 2021 and August 2023. This includes the Tesla Models S and X, which have prices exceeding the 30D MSRP cap through the end of our sample in August 2023, and the Mercedes EQE, which only entered the market in spring 2023 and whose price exceeds the MSRP cap.

We exclude these final three groups from our analysis due to multiple factors: in the case of the Excluded Jan 2023 and Always excluded groups, they represent a very small proportion of the overall market and are excluded because of MSRP requirements rather than because of domestic sourcing provisions; in the case of the Always included and Always excluded groups, they experienced no eligibility change due to the policy changes in the IRA. While analysis is made more difficult for these groups due to the small numer of constitutent models/submodels, we note that our core findings (and in particular the pooled results in Figures A4 and **??**) are robust to including these groups.

The MSRP requirements for 30D credit eligibility are set at $80,000 for vans, SUVs, and pickup trucks and $55,000 for other vehicles (including sedans) (Internal Revenue Service, 2023). Note that, early in 2023 after these requirements were put into effect, there was some uncertainty around the classification of popular models including the Tesla Model Y, which ended in the Treasury Department adopting a more expansive definition of "SUV" which enabled the Model Y to qualify under the more lax $80,000 MSRP limit (Picchi, 2023).

In addition to the contstraints placed on vehicles' eligibility for 30D credits on the basis of assembly and sourcing requirements, the IRA also imposed eligibility constraints on the buyer side. Specifically, a purchaser of a new electric vehicle is only eligible to recieve the 30D credit if, in at least one of the year they take delivery or the previoius year, their adjusted gross income does not exceed: $300,000 for married couples filing jointly, $225,000 for heads of households, and $150,000 for all other filers (Internal Revenue Service, 2023). See Figure A1 for contextualization of these

limits relative to the income distribution of those who had historically claimed the pre-IRA credit. Note that all of these requirements can be circumvented by leasing the vehicle, as the 45W credit for commercial purchases is not subject to such restrictions.

D Empirical Estimates

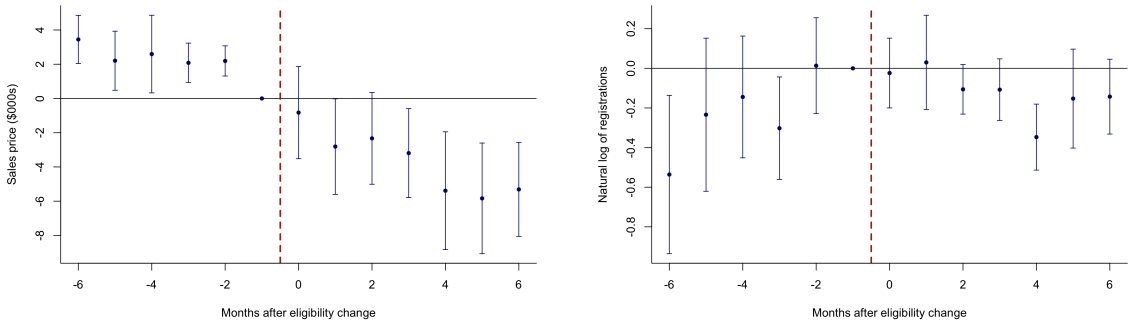
In this appendix, we provide estimates for variations on the main regressions reported in Section 3. We first consider the estimates obtained from pooling across the three different events included in Figures 5 and 6. Doing so requires some modifications to the earlier Equation 1. In particular, as some of the vehicles under consideration undergo a change in eligibility which is a loss of the credit, while others become eligibile for the credit, we must adjust accordingly our notion of treatment. In Equation 1, the treatment intensity is given by C_j, the absolute value of the change in credit a submodel experienced, normalized by the maximum credit amount of \$7,500. In contrast, Equation 2 (which will form the basis of the pooled estimation) scales treatment by C_j^*, which is simply the change in credit a submodel experiences, normalized by the maximum credit amount of \$7,500; that is, $\left|C_j^*\right| = C_j$ for all j. This allows us to interpret τ_r^* as the impact of being eligible for a 30D credit, as submodels which lost eligibility will have a negative value for C_j^*. As before, we include submodel, date, and Tesla month-of-quarter fixed effects.

$$y_{jt} = \sum_{r=\underline{R}}^{\overline{R}} \tau_r^* C_j^* \cdot 1\left\{t - r = t_j^*\right\} + \beta X_{jt} + \phi_j + \nu_t + \varepsilon_{jt}. \tag{2}$$

The results from estimating Equation 2 on all three events, using as before ICE vehicles as the control, are shown in Figure A4; the corresponding results, with Tesla vehicles excluded, are shown in Figure A5.

Figure A4: **California Price and Registrations Event Studies, Pooled Estimation**

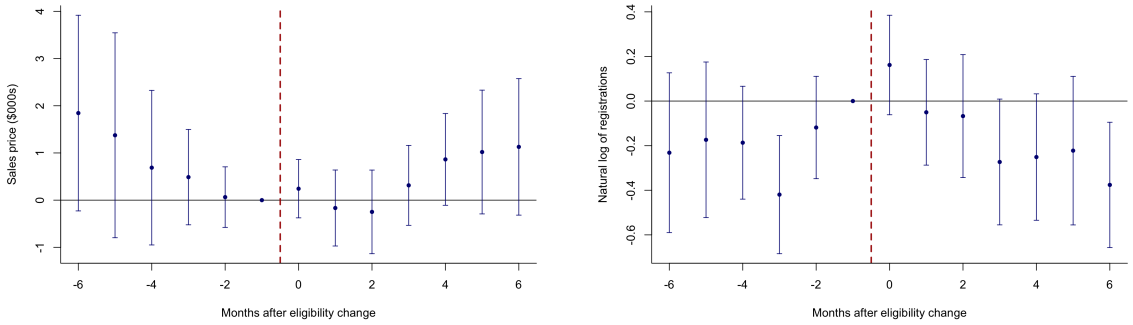
(a) **Price Event Study Plot, Pooled** (b) **Registrations Study Plot, Pooled**



Notes: Panel (a) presents estimates of the relationship between eligibility changes and average sales price using equation (2) across each of the three considered eligibility groups, mirroring Figure 5; similarly, panel (b) presents estimates of the relationship between eligibility changes and registrations which mirror 6. In all regressions, the control group is comprised of ICE vehicles (including non-plug-in hybrids). Standard errors are clustered at the model level.

Figure A5: **California Price and Registrations Event Studies, Pooled Estimation, Excluding Tesla**

(a) **Price Event Study Plot, Pooled** (b) **Registrations Study Plot, Pooled**



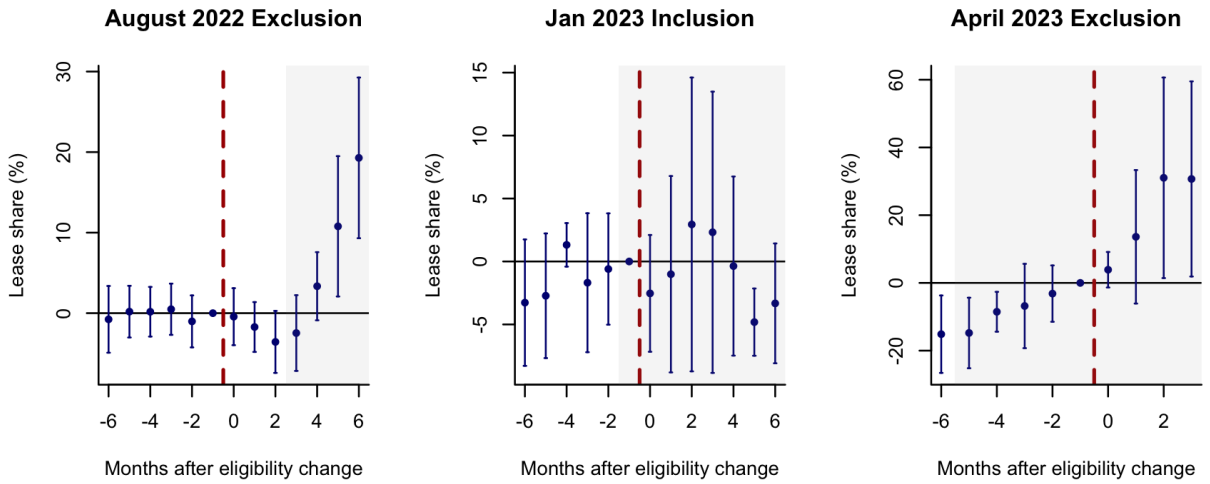
Notes: Panel (a) presents estimates of the relationship between eligibility changes and average sales price using equation (2) across each of the three considered eligibility groups, mirroring Figure 5; similarly, panel (b) presents estimates of the relationship between eligibility changes and registrations which mirror 6. In all regressions, the control group is comprised of ICE vehicles (including non-plug-in hybrids). Standard errors are clustered at the model level.

Finally, we also provide results analogous to Figure 9, where we consider the impact of 30D credit eligibility changes on lease share. Figure A6 shows these results, which come directly from the estimation of Equation 1 as in Figures 5 and 6. These figures suggest that there is no direct effect of the 30D eligibility change on leasing patterns, except when mediated by the 45W leasing offers; notice, for example, that the Excluded Aug 2022 group have no change in the months immediately

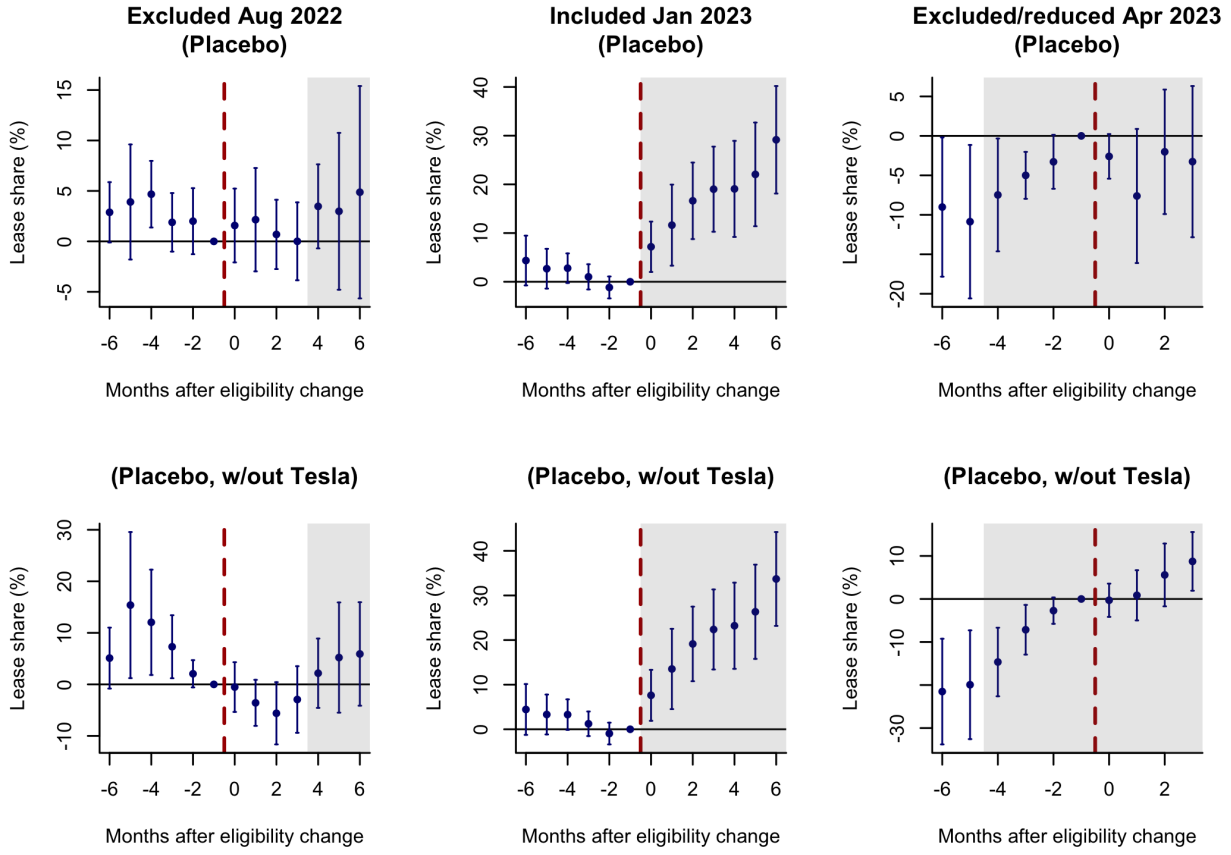
following the passage of the IRA (their event time), but the lease share increases dramatically from post-period 4 on, which coincides exactly with the beginning of 2023. The lack of a noticeable response for the Included Jan 2023 group can largely be attributed to Tesla's anamolous leasing patterns, which appear to have persisted even for their more expensive vehicles (which are not eligible for the 30D credit) after the 45W policy change in January of 2023.

Figure A6: **California Lease Share Event Studies for Each Eligibility Group**

(a) **Event Study Plots by Eligibility Group**



(b) **Placebo Event Study Plots by Eligibility Group**



Notes: Panel (a) presents estimates of the relationship between eligibility changes and lease share using equation (1) for each of the three considered eligibility groups. Note that treatment timing here is determined by 30D eligibility changes, not the 45W policy change in January of 2023. Panel (b) presents estimates using the same equation and control group, but on EVs not included in the associated eligibility group. We present placebo results both with and without Tesla vehicles. Note that the difference between the *Included Jan 2023 (Placebo)* and *(Placebo, w/out Tesla)* are only the Tesla models not made eligible in January of 2023, namely the Models S and X. Standard errors are clustered at the model level.