Cracking the Chicken-and-Egg Problem:

Evidence from China's Electric Vehicle Infrastructure Development

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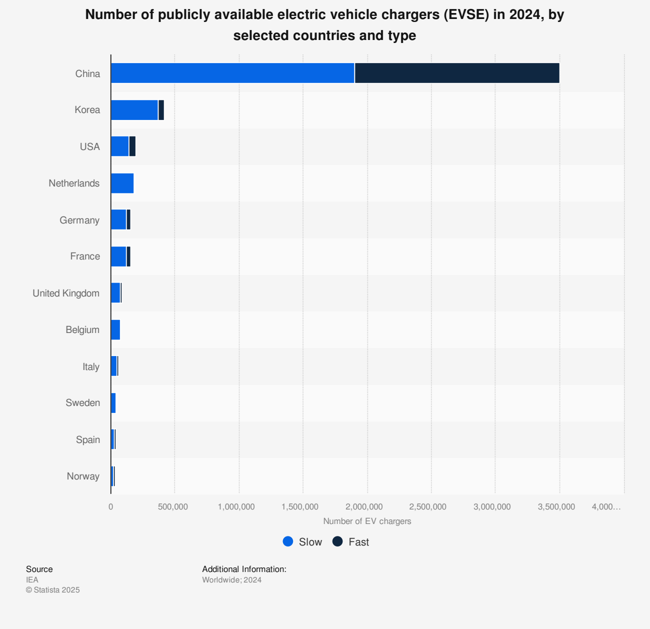
Classic “chicken and egg” problem in EV markets

Source: gridx.ai

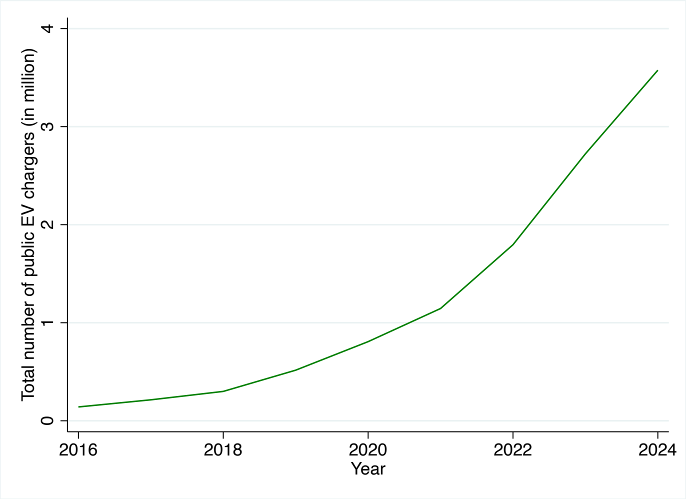
- Consumers are reluctant to buy EVs when charging network is sparse
- Firms are reluctant to build charging stations when there are few EVs

- Without intervention, markets can remain stuck in a low-EV, low-infrastructure equilibrium, even through a high-EV, high-infrastructure equilibrium with higher social welfare may exist

A global struggle—with China as one of the key exceptions



Total number of public EV chargers in China (in million)



- A rapid growth from 2016 (141,254 chargers) to 2024 (3,575,819 chargers)

Research question: What explains China's rapid expansion of EV infrastructure, and what we can learn from it?

1. What we do:
   - Data: Comprehensive data on EV charger, sales, subsidy data in 2016-24
   - Identification: Staggered rollouts of local governments' charger subsidies
2. (Very) preliminary findings:
   - Electricity subsidy for charger providers induced greater charger growth
   - Construction subsidy for chargers had statistically insignificant effects
3. Work in progress:
   - Collecting more granular data on chargers, EV sales, and subsidy policies
   - Thinking more about feedback effects between chargers and EV demand

Related litereature

Evidence from US

- Shanjun Li, Lang Tong, Jianwei Xing, Yiyi Zhou (2017)
  - One of the first papers that studied network effects of EV chargers
  - Evidence from early days of EV adoption in the US (2011-13)
- Jing Li (2023): Inefficiency of incompatible EV chargers in the US
  - As we will describe, China has solved the compatibility problem in 2016

Evidence from Norway

- Katalin Springel (2021)
  - A strong positive connection between EV purchases and charger subsidies
  - Charger subsidies more effective than price subsidies to increase EV sales

Related litereature

Evidence from China

- Shanjun Li, Xianglei Zhu, Yiding Ma, Fan Zhang, Hui Zhou (2022)
  - Data: 2015-18
  - Focus was EV sales—which government policie (consumer subsidies) influenced EV sales
- Our study
  - Data: 2016-2024—A rapid charger growth started around 2020
  - Our focus is the network infrastructure development (EV chargers)
  - Which policies influenced EV charger growth and ultimately EV adoption

Road map of the talk

1. Introduction
2. Background
3. Data and Descriptive Evidence
4. Empirical Analysis and Preliminary Results
5. Next Steps

Background

EV public charging stations in China

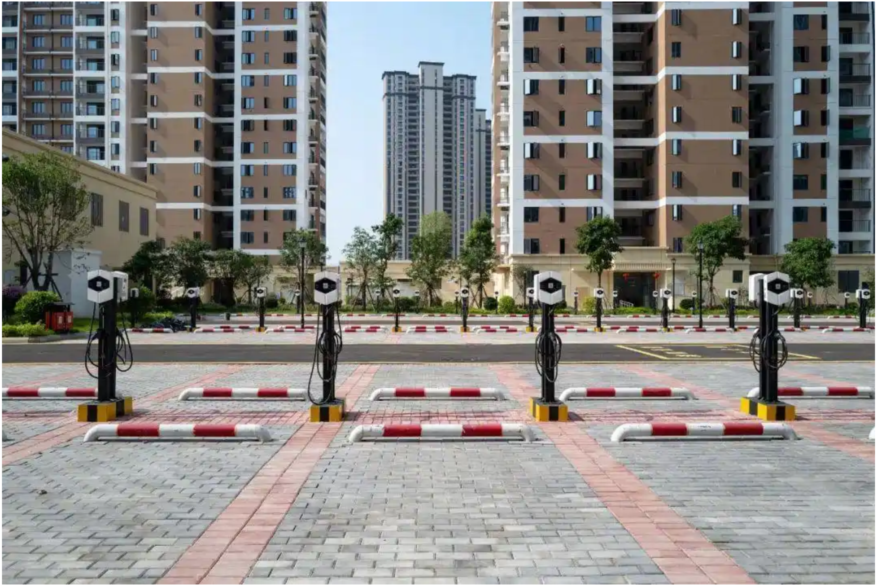
- Regulated market—firms that build charging stations need to apply for land-use and construction permits from the local government (city)
  - Private firms are the leading providers (90% of charging stations)

- Compatibility—since 2016, China has mandated all EVs and public chargers to follow the unified GB/T 20234 charging standard
  - Every EV sold in China uses the same connector type
  - Every public charging station is compatible with every vehicle (including Tesla super chargers)
  - This allowed China to avoid "fragmented charging standard" problems seen in the U.S. and Europe

Why do public charging stations matter?

- Most Chinese households live in apartments with no home chargers
- Public charging stations have expanded to highways and rural areas
  - Broadened the infrastructure network to allow long-distance travel

EV public charging stations in cities (near apartments)



EV public charging stations in highways

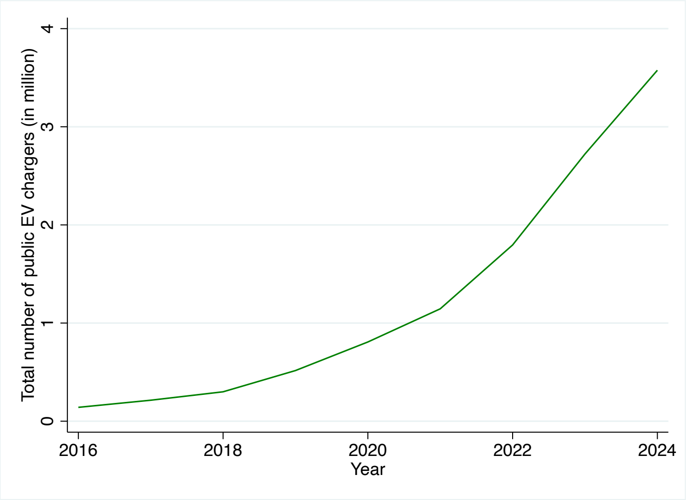
EV public charging stations in rural areas

Data and Descriptive Evidence

1) EV chargers data

- Data in hand and analyzed
  - Number of public EV chargers by province and year in 2016-2024
- Data in the process of obtaining
  - Number of public EV chargers by city and half-year in 2016-2024

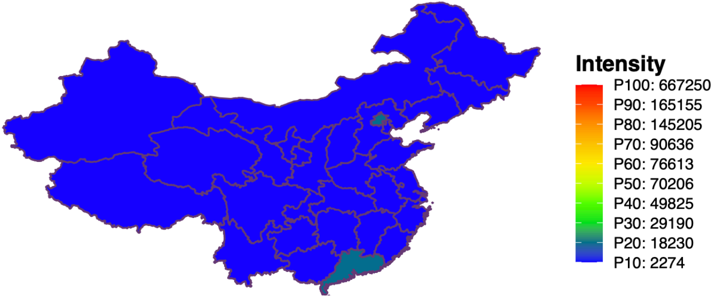
Total number of public EV chargers in China (in million)



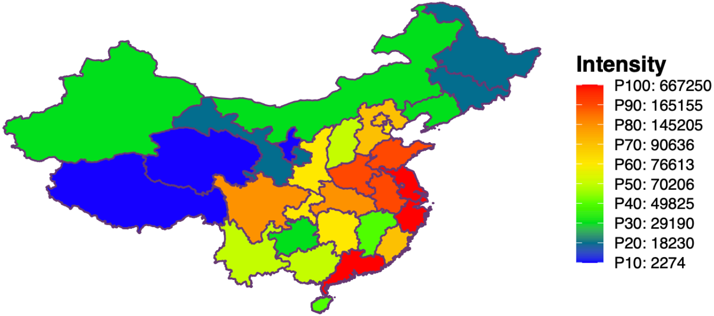
- A rapid growth from 2016 (141,254 chargers) to 2024 (3,575,819 chargers)

Number of public EV chargers in 2018 and 2024

2018



2024



2) Subsidy policy data

- Data in hand and analyzed
  - Subsidy policies to EV charger providers by province and month
  - In provinces where policies were made by cities, we analyze the maximum amount of subsidy (if any) of the province
- Data in the process of obtaining
  - Subsidy policies to EV charger providers by city and month
  - EV purchase subsidies (potentially another key policy instrument)

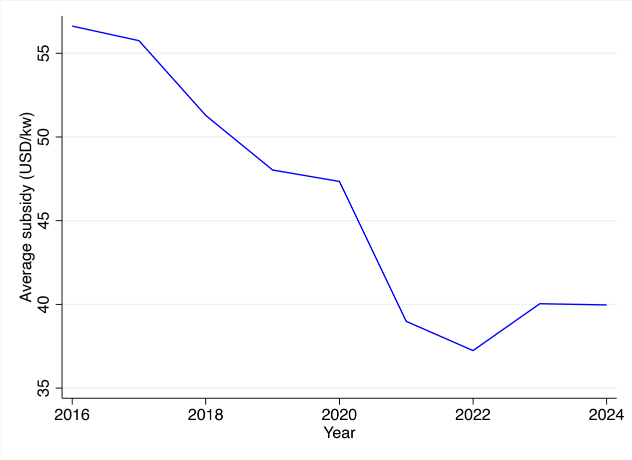
Two subsidy policies for EV infrastructure development

EV charger firms receive two subsidies to build and operate chargers:

- Policy 1: Construction subsidies
  - Cash subsidy per kw of chargers, amount varying by province & time
  - For example, in Guangdong province, fast-chargers were subsidized by about $77/kw, and slow-chargers $14/kw
  - Note that the average construction cost in this period is 46 USD/kW

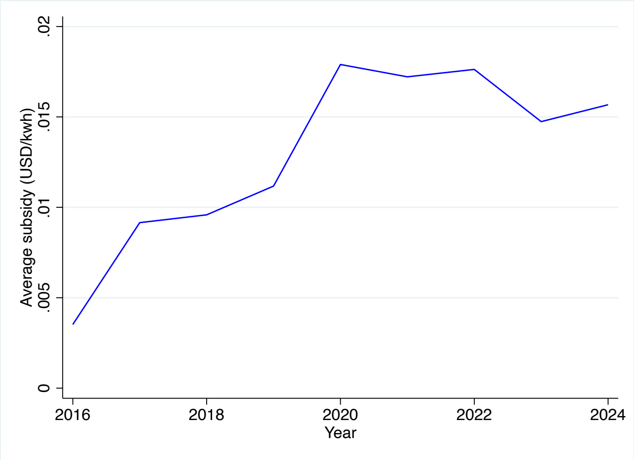
- Policy 2: Operation subsidies for electricity costs
  - Utilities charge EV charging facilities a two-part tariff: fixed cost based on installed capacity (waived in our period) + variable cost
  - Variable cost subsidy: staggered rollout and variation by province & time
  - For example, in Beijing, charger providers received a $0.03/kwh subsidy for electricity—electricity price was $0.16 (peak) and $0.08 (off-peak)

Subsidy for construction costs: average amount (USD/kw)



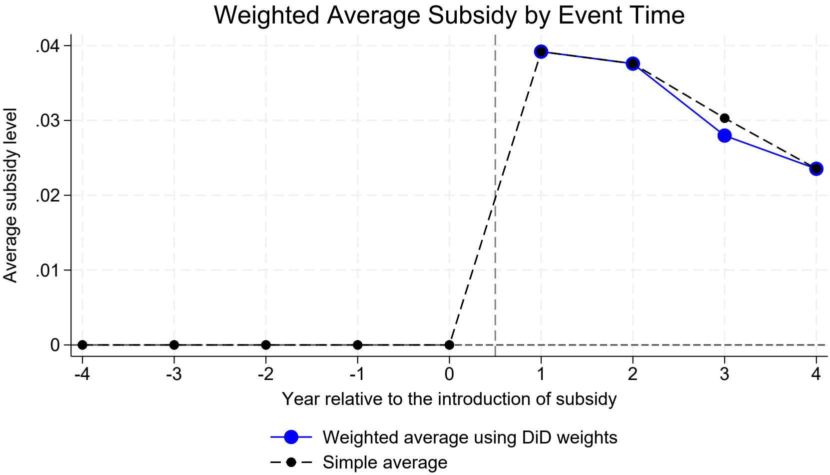
- Average subsidies of fast and slow chargers
- Note that the average construction cost ranges from 98 to 183 USD/kW

Subsidy for electricity costs: average amount (USD/kwh)



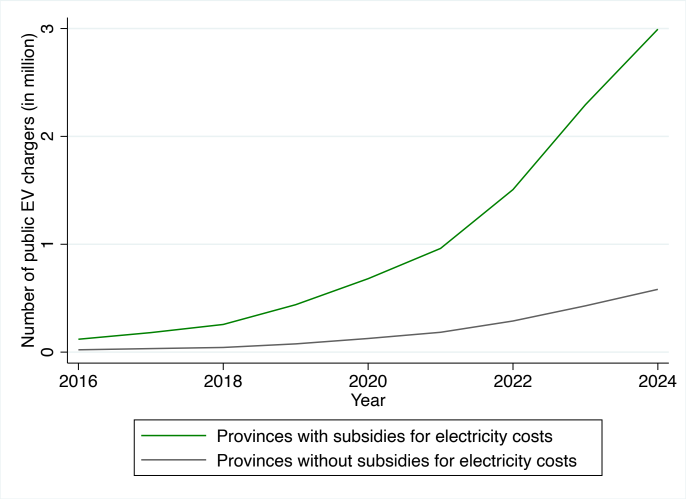
- About half the provinces introduced this subsidy with a staggered rollout
- Note that the average electricity cost in this period is 0.12 USD/kWh

Subsidy for electricity costs: by event time (USD/kwh)



- Note that the average electricity cost in this period is 0.12 USD/kWh

Number of public EV chargers: Provinces with and without subsidies for electricity costs



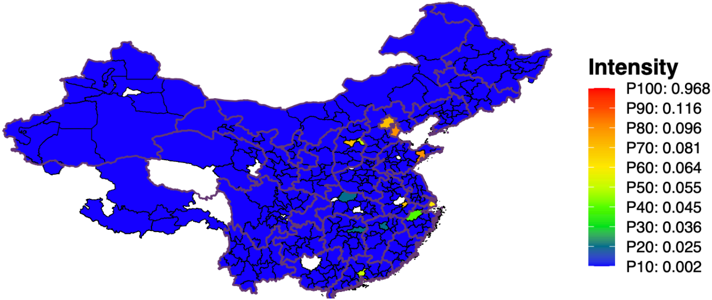
- We observe greater growth in chargers in provinces with the subsidy

3) Car sales data

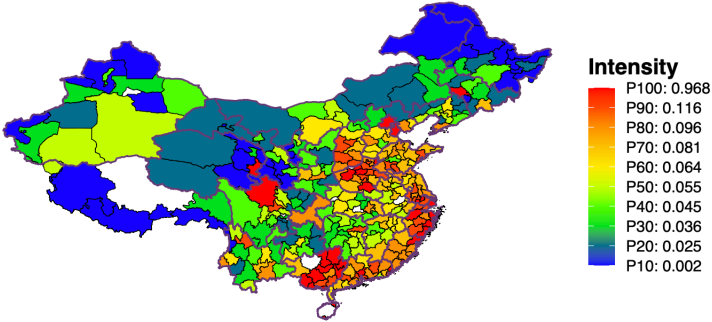
- Data in hand and analyzed
  - All car sales data by city, month, and model in 2016-2020
  - We aggregate the data to province by year
- Data in the process of obtaining
  - Update the data to extend our sample period to 2016-2025

EV sales ratio in 2018 and 2024

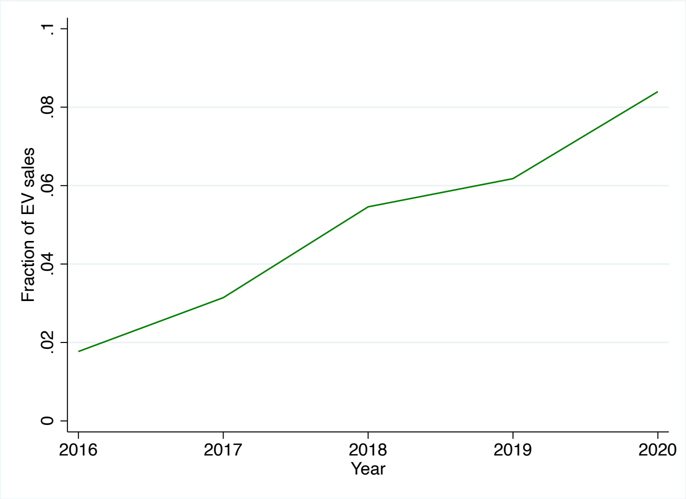
2018



2021

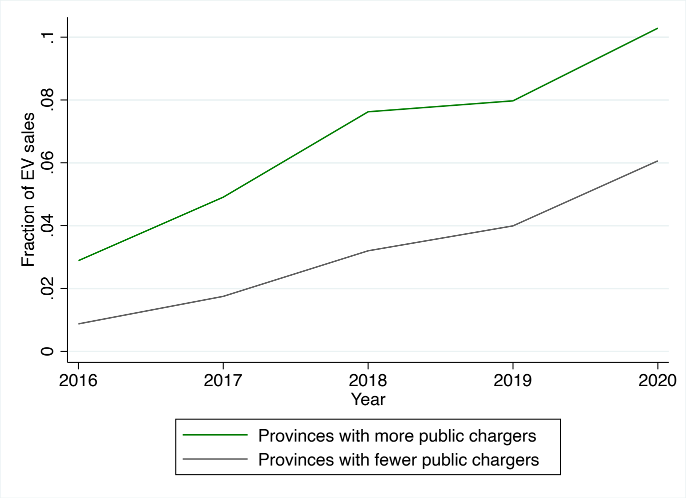


EV sales ratio—National average



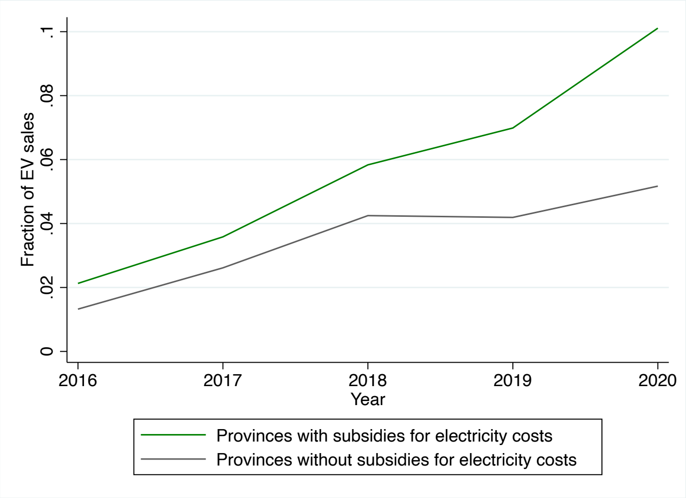
- EV sales ratio = (EV sales/all car sales) in the new car market

EV sales ratio—Provinces with more vs. fewer chargers



- We divide provinces to two groups based on the number of chargers in 2020
- We observe greater growth in EV ratios in provinces with more chargers

EV sales ratio—Provinces with/without electricity subsidy



- Provinces with electricity subsidy for chargers vs. other provinces
- We observe greater growth in EV ratios in provinces with the subsidy

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Empirical Analysis and Preliminary Results

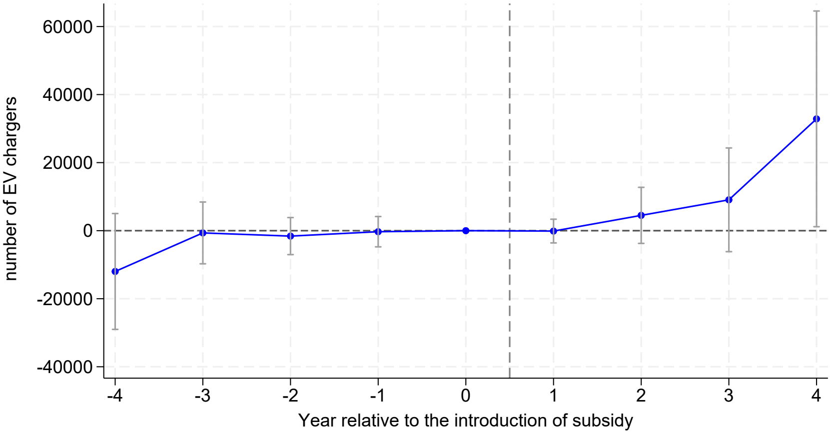
Staggered difference-in-differences estimation

$$y_{it} = \alpha_i + \gamma_t + \sum_{k=a}^{b} \phi_k D_{it}^k + u_{it},$$

- y_{it}: Outcome variable in province i in year t (e.g. the number of EV chargers)
- α_i: Province fixed effects
- γ_t: Year fixed effects.
- $k \in [a, b]$: Event time relative to the first year of treatment (e.g. electricity subsidy)
- We use de Chaisemartin, d'Haultfoeuille, Pasquier, Sow and Vazquez-Bare (2025) to allow for heterogeneous treatment effects across time and cohorts

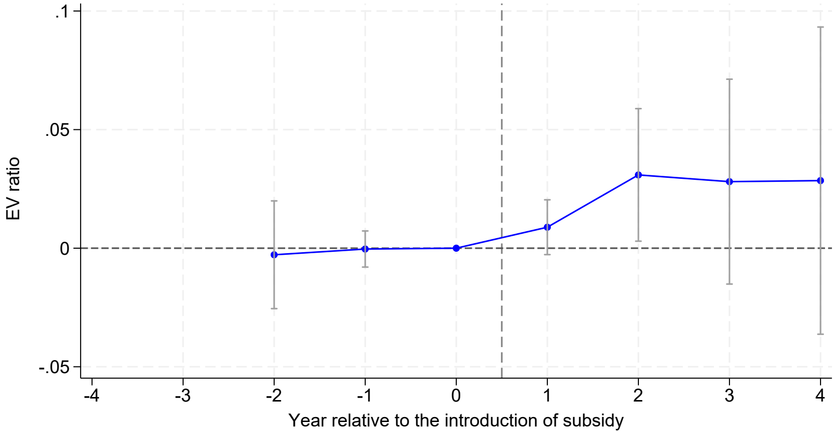
Results 1: Effect of Electricity Subsidy

1) Effect of electricity subsidy on the number of chargers



- Result suggests that electricity subsidies had an positive effect

2) Effect of electricity subsidies on EV sales ratio



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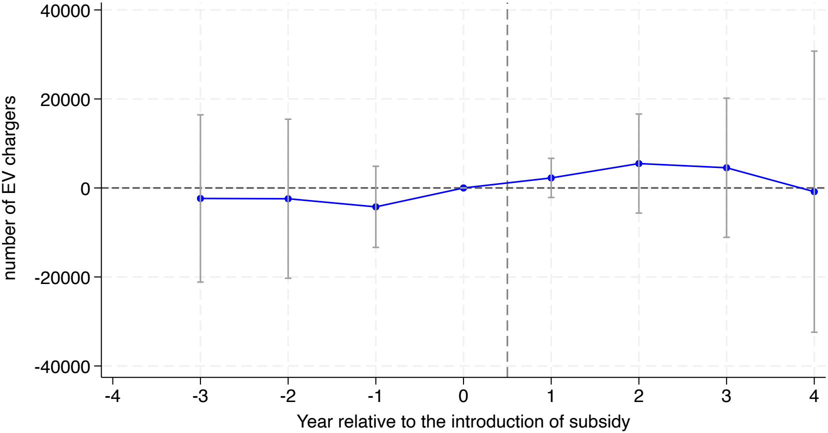
Effects of electricity subsidies

	EV chargers (province)		EV sales ratio (city)	
	(1)	(2)	(3)	(4)
1(Subsidy)	10,591		0.010	
	(6,719)		(0.003)	
Subsidy (USD/kWh)		491,360		0.277
		(208,972)		(0.071)
Observations	279	279	1,572	1,572
Year FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	No	No
City FE	No	No	Yes	Yes

- Columns 1 & 3 show the effect of a binary 1(Subsidy) variable
- Columns 2 & 4 show the effect of a continuous Subsidy (USD/kWh)
  - Column 2: 1 cent increase in subsidy $\rightarrow$ a 491 increase in chargers
  - Column 4: 1 cent increase in subsidy $\rightarrow$ a 0.0027 increase in EV ratio

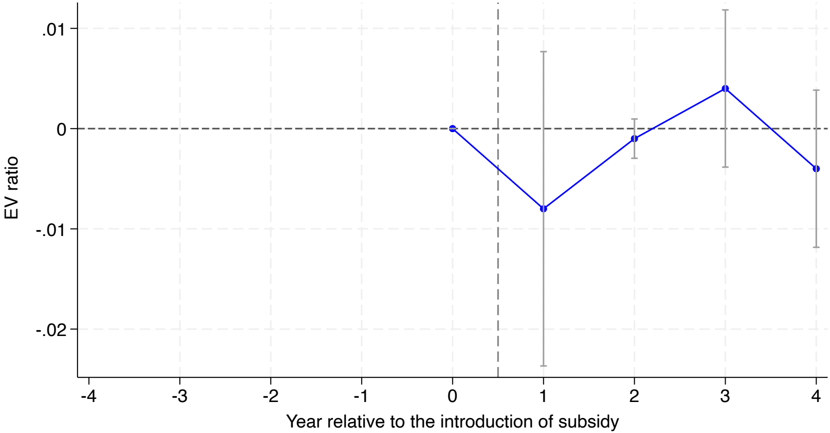
Results 2: Effect of Construction Subsidy

3) Effect of construction subsidy on the N of chargers



- We find statistically insignificant effects of construction subsidies
- However, this can be due to data limitations (our new data might help)

4) Effect of construction subsidy on the EV sales ratio



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Next steps

1. Collect city-level data on chargers and subsidy policies (in progress)
   - Collecting city-level policies is not a trivial work
   - However, city-level variation might provide more precision in our estimation
2. Collect data on province- and city-level EV purchase subsidy policies
   - Positively shifting EV demand might have contributed to the constructions of EV chargers

Feedback effects between EV chargers and EV demand

- Multinational multi-product firm f's profit can be written by:

$$\text{(Demand for EV)}\quad \ln q_t = \beta_0 + \beta_1 \ln N_t + \beta_2 \ln p_t + \beta_3 x_t + \epsilon_t$$
$$\text{(Number of chargers)}\quad \ln N_t = \gamma_0 + \gamma_1 Q_t + \gamma_2 z_t + u_t$$

  - q_t: EV sales at time t
  - N_t: Number of EV chargers
  - p_t: Price of EV
  - x_t: Other vehicle attributes
  - Q_t: Total EV on the road
  - z_t: Other covariates

Thank you! Very preliminary and feedback welcome!

Appendix