# Forward Contract Markets in the Energy Transition:

## Evidence from the Chilean Electricity Market

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# Motivation: How does the energy transition change electricity prices?

- Most existing research has focused on wholesale spot markets
  - However, end-use consumers generally do not pay spot market prices directly
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- 1) Large industrial customers (called "libre" customers in Chile)
  - Manufacturing, mining, large commercial businesses, data centers, etc.
  - Sign long-term bilateral contracts directly with electricity suppliers at negotiated prices.
  - Some of these contracts are often called as "power purchase agreements" (PPAs)

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- 2) Small business/residential customers (called "regulado" customers in Chile)
  - Purchase electricity from distribution companies with regulated prices

SUPPLY SIDE

DEMAND SIDE

**Generation companies**

## 1 Forward Contracts

- Long-term bilateral contracts (typically many years)
- Specify quantity (MWh), price ($/MWh)
- Contracts are financial (not physical)
- Allocate price risk between parties

Distribution Companies

**Regulated Customers ("Regulado")**

- Served by distribution companies
- Do not negotiate prices individually
- Consumers pay regulated tariffs

## 2 Spot Market

**1. DISPATCH**

Every hour, the system dispatches generation based on lowest cost and system constraints.

**2. SPOT PRICE**

The marginal cost of the last unit needed to meet demand sets the hourly spot price ($/MWh).

**3. SETTLEMENT**

All injections and withdrawals are valued at the spot price.

**Free ("Libre") Customers**

- Large industrial and commercial consumers
- Mining, manufacturing, data centers, etc.
- Can choose their supplier
- Negotiate bilateral contracts directly with generators

**Sellers get = Contract price + (Spot Price at Seller Node) - (Spot Price at Buyer Node)**

**Consumers pay = Contracted price**

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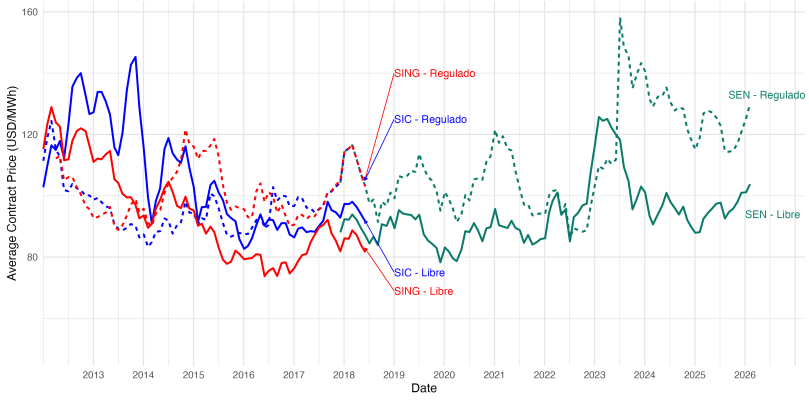
- Energy transition may affect contract prices more rapidly than regulated prices because:
  - Solar and wind plants (high FC and zero MC) are usually built with forward contracts
  - Regulated prices include substantial non-generation costs and adjust more slowly

# Many countries, including Chile, are experiencing this phenomenon




- Libre prices have become more attractive after renewable expansion
  - Exception is 2022-23, when government capped regulated prices in a short-term
- Which firms benefited most? Did it create labor opportunities? What tensions can arise?

# Research questions, preliminary results, and next steps

1. How did Chile's market integration and renewable expansion change electricity prices?
   - Use forward contract data to examine the price impacts on end-use electricity consumers
   - Preliminary results suggest large industrial consumers had substantial price declines
   - To do: We will develop a search model of contracting to quantify the welfare implications, including potential tension between industrial customers and regulated customers.

2. How did renewable expansion affect the broader economy?
   - Large electricity users—such as manufacturing firms, mining companies, large commercial businesses, and data centers—may have benefited substantially.
   - Small businesses may have benefited less.
   - Use confidential administrative data from the Central Bank of Chile to examine impacts on:
     - Employment and wages
     - Production input choice
     - Output, investment, productivity
     - Relocation of production locations
   - To do: We will estimate the production function to investigate implications for productivity

# Road map of the talk

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2. Background and Data
3. Descriptive Evidence
4. Next Steps

# Background and Data

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# Chile's electricity market

1. Regulado customers (*Clientes Regulado*)
   - Households and small businesses
   - Electricity tariffs are regulated by the Comisión Nacional de Energía (CNE)
   - Consumers get electricity from distribution companies

2. Libre customers (*Clientes Libres*)
   - Large industrial and commercial consumers (e.g. mining, manufacturing, data centers).
   - Consumers freely choose contracts with any suppliers
   - Eligibility is based on the connected capacity
     - Below 500 kW: Regulado
     - Above 5,000 kW: Libre
     - Between 500 and 5,000 kW: Customers can self-select into either

3. Sellers (Generation companies with physical generation capacity)
   - Generate electricity & dispatched by the cost-based dispatch in the spot market
   - Sell forward contacts to customers

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# Data

# 1) Electricity Market Data

1. Electricity transactions between seller and buyers (2012–2025)
   - **Source:** Coordinador Eléctrico Nacional (CEN)—Chile's independent system operator (ISO)
   - **Unit of observation:** Hourly quantity for each supplier-buyer pair
   - **Suppliers:** Electricity generation firms
   - **Buyers:** Libre customers (via direct contracts with suppliers) and Regulado customers (electricity distribution companies that serve residential and small businesses)

2. Hourly electricity generation (2017–2025)
   - **Source:** Coordinador Eléctrico Nacional (CEN)—Chile's independent system operator (ISO)
   - **Unit of observation:** Hourly quantity at the generator level

# 2) Tax Records from Central Bank of Chile

- Electronic Invoices (Factura): Tax records on nearly all B2B transactions
  - **Source:** Electronic Tax Documents (DTE) from the Chilean Internal Revenue Service (SII)
  - **Period:** 2014–2026
  - **Unit of observation:** Firm-to-firm transaction level (i.e. each bill of sales)
  - **Variables:** Anodized identifiers for sellers and buyers, transaction value, quantity, price, product descriptions, economic activity classification of sellers and buyers, and etc.
  - **Firm coverage:** 636 thousand firms, 357 million bills of the 115 economic sectors
  - This dataset allows us to observe payments between electricity sellers and buyers

- Additional firm-level data
  - Labor Directorate records: Employment, wages, labor income
  - Corporate tax forms: Capital, fixed assets, depreciation, and investment
  - Our ultimate goal is to study the impacts on these economic outcomes (not yet today)

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# Preliminary Findings (Work in Progress)

# Today, we show the impact of market integration on forward contracts

Interconnection (Nov. 2017)

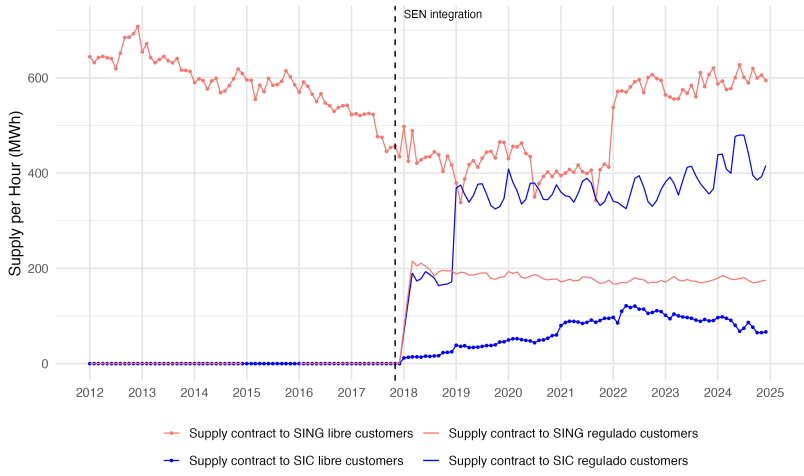

Reinforcement (June 2019)


- In 2017, SING and SIC were integrated (via Atacama-Antofagasta line) to become SEN
- In 2019, a reinforcement line was built (Atacama-Santiago line)

# 1) Forward Contract Quantities (MWh)

# Market integration → SING-suppliers began signing contracts in SIC

Example: **Engie** (supplier that used to have contracts only in SING)




- **Engie** entered the SIC (south) contract market after integration

# This comes from forward contract sales, rather than changes in generation

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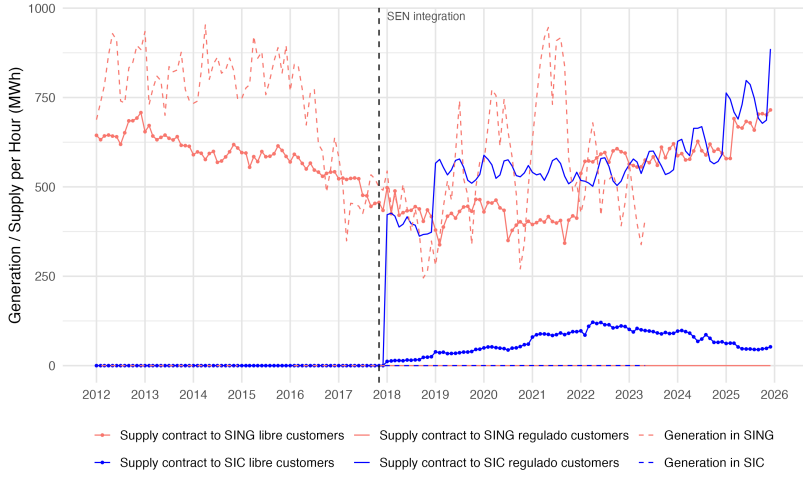
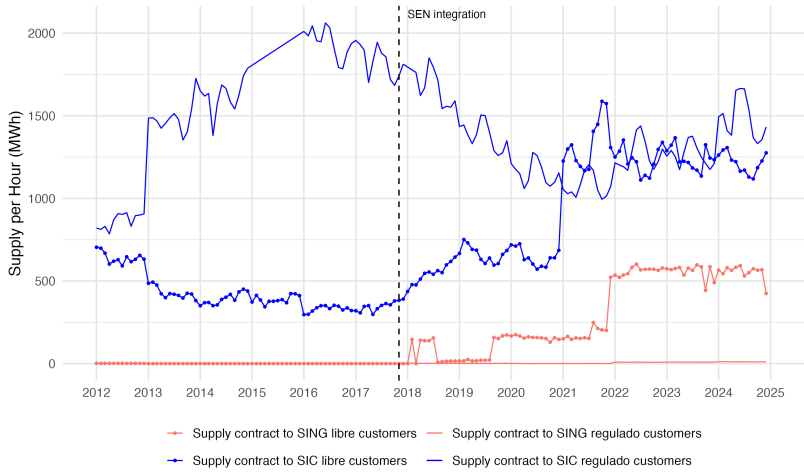



- **Engie**'s generation (dashed line) remains similar before/after the integration

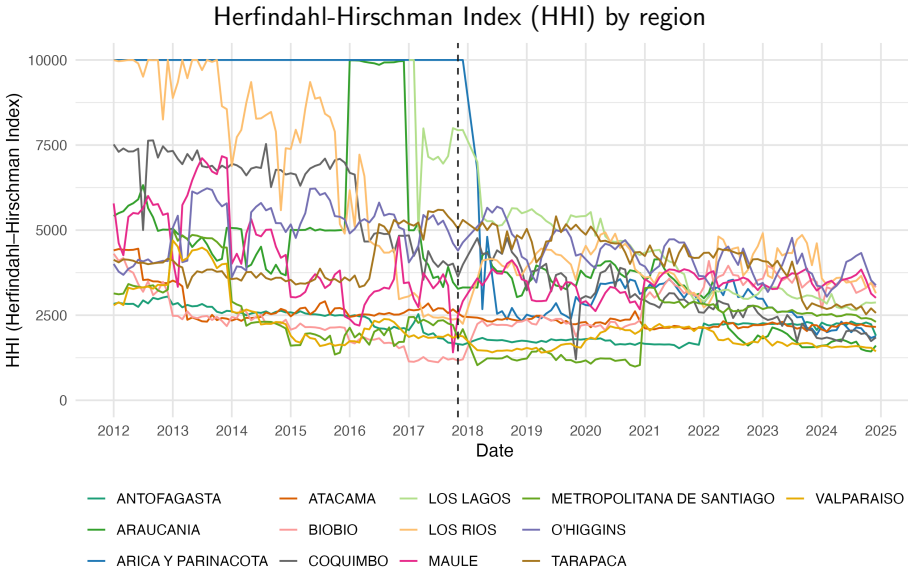
# Market integration → SIC-suppliers began signing contracts in SING

Example: **Enel** (supplier that used to have contracts only in SIC)



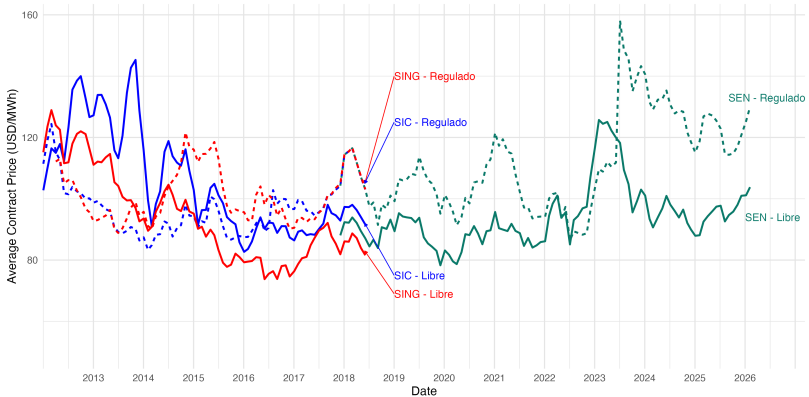

- **Engie** entered the SING (north) contract market after integration

# Market integration → Declines in regional HHIs in the contract market



# 2) Forward Contract Prices (USD/MWh)

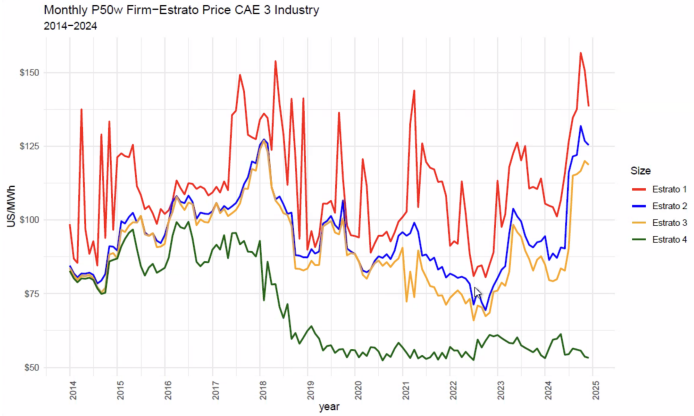
# On average, Libre prices have become lower than Regulado prices




- Libre prices (PPAs) have become more attractive after renewable expansion
  - Exception is 2022-23, when government capped regulated prices in a short-term

# Especially, large manufacturing firms' electricity prices declined

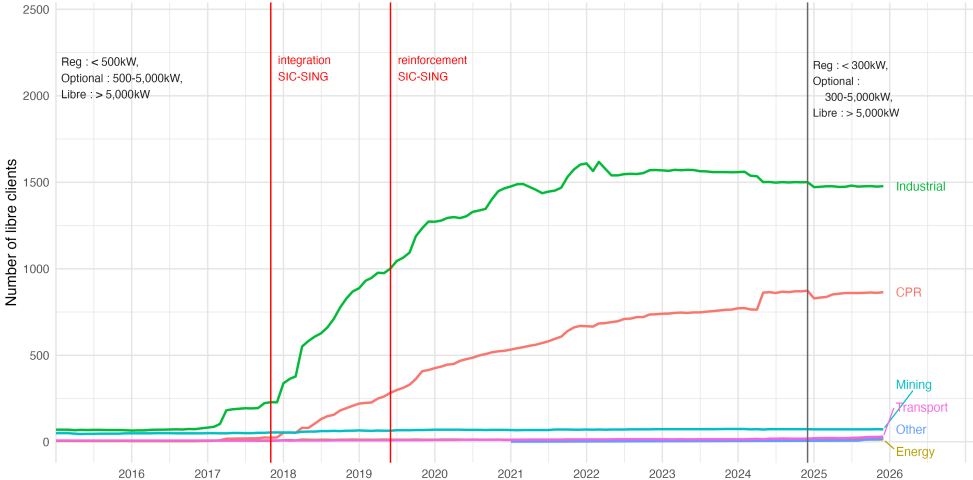
Median electricity prices for manufacturing firms (by quartile based on their size)




- 4th quartile group (green line) had a price decline after the market integration
- Large industrial customers benefited from the libre contract market that became more competitive

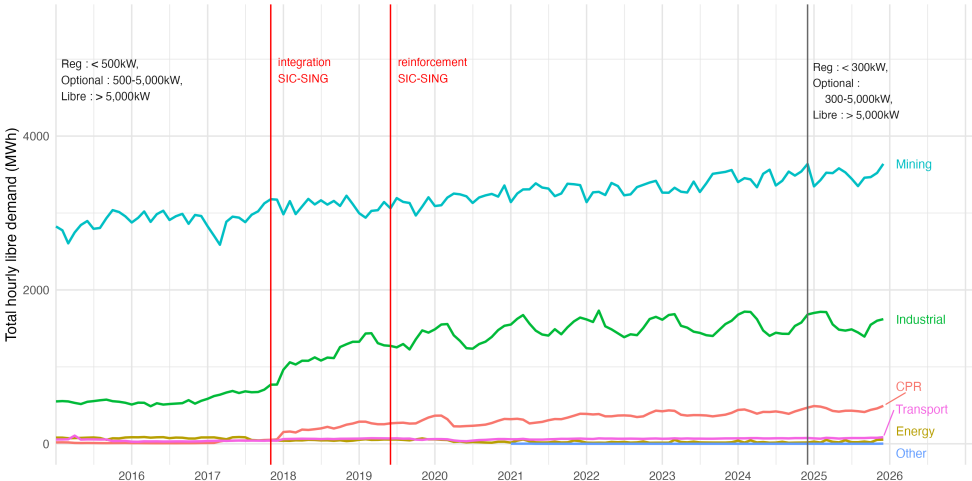
## 3) Consumer Entry into the Libre (i.e. freely contracting) Market

# Large increases in Libre customers after the market integration




- New entries mostly come from the industrial and commercial sectors

# This is in terms of total demand

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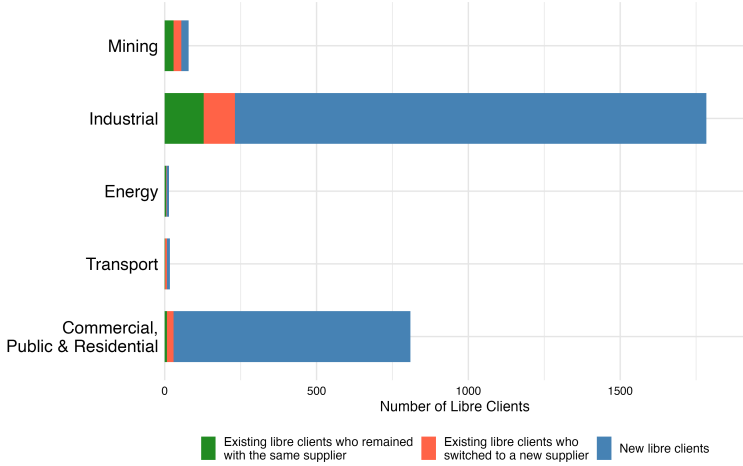
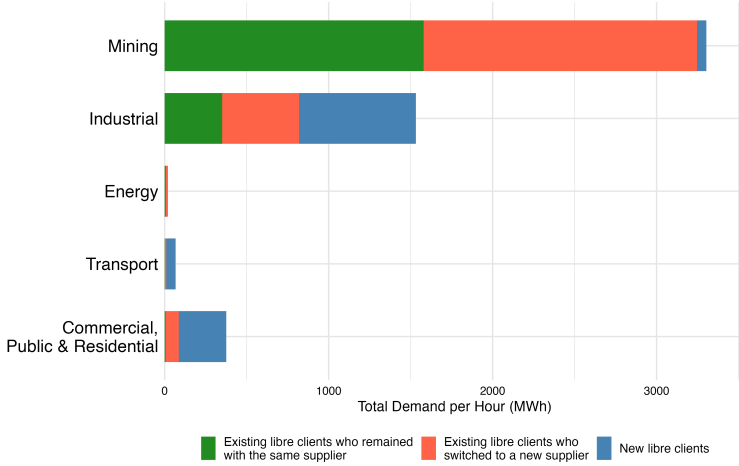
# 4) Consumer Choice of Suppliers

# Consumer choice of suppliers in 2022 relative to 2017 (N of consumers)




- Industrial is the largest sector in terms of the number of Libre consumers
- After market integration, about a half of existing Libre clients switched their suppliers

# Consumer choice of suppliers in 2022 relative to 2017 (weighted by MWh)




- Mining is the largest sector in terms of MWh
- After market integration, about a half of existing Libre clients switched their suppliers

## 5) Economic Impacts on Manufacturing Customers (still very much work in progress)

- We want to ask whether the changes in electricity prices resulted in changes in economic outcomes (production, productivity, etc.)
- Currently focusing on manufacturing sector
- We can extend the analysis to other sectors

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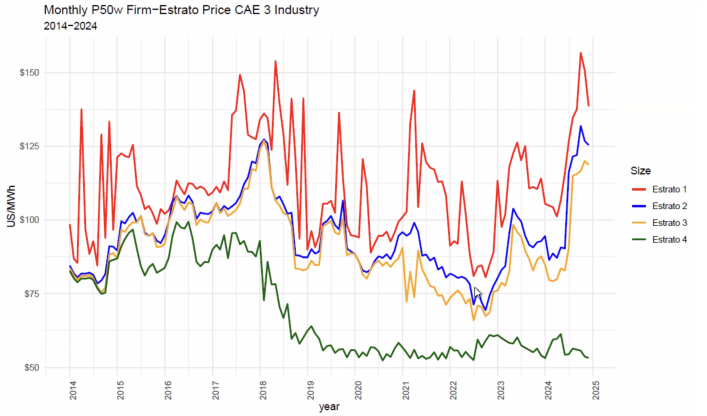
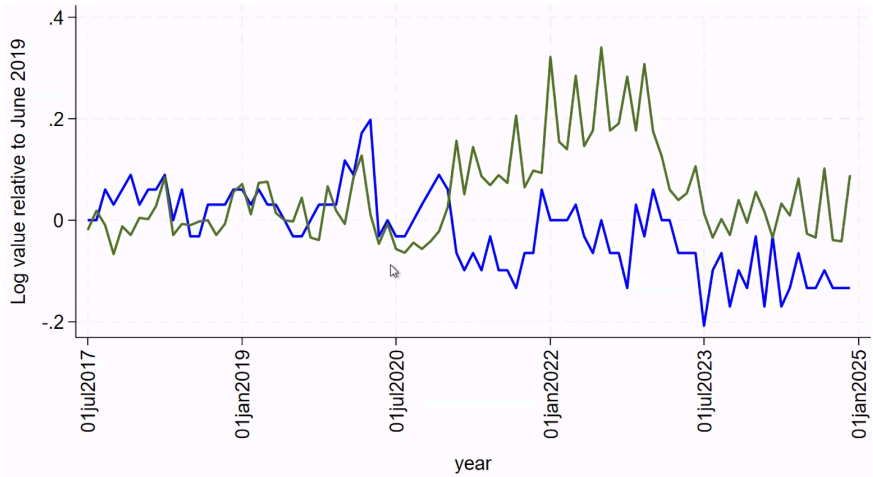


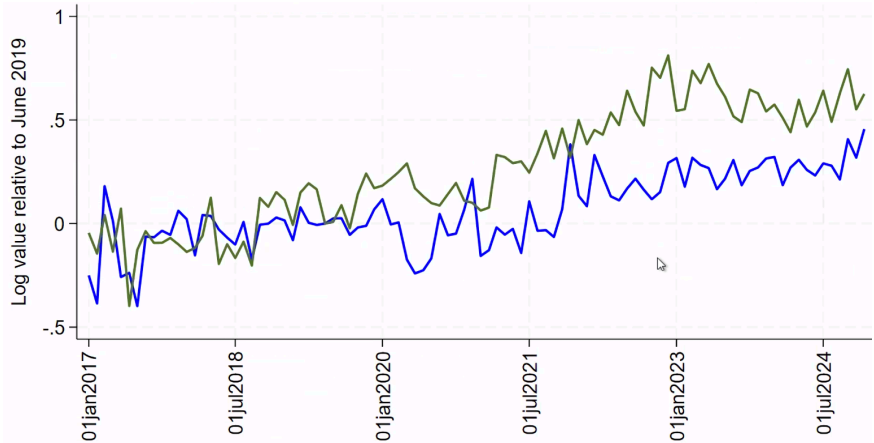

- Did it affect firms' inputs (e.g., employment and investment) and outputs?

# Employment: Large firms' employment increased relative to others




- Log value relative to June 2019 (the begging of the market integration)

# Sales: Large firms' sales increased relative to others

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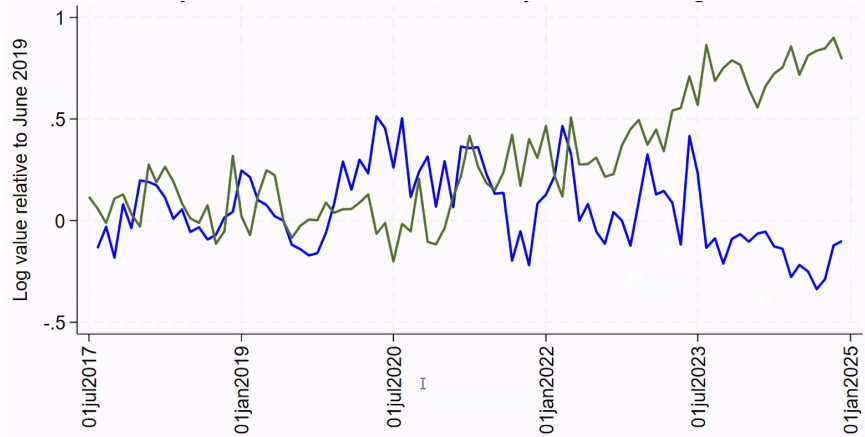
# Electricity consumption: Large firms' usage increased relative to others

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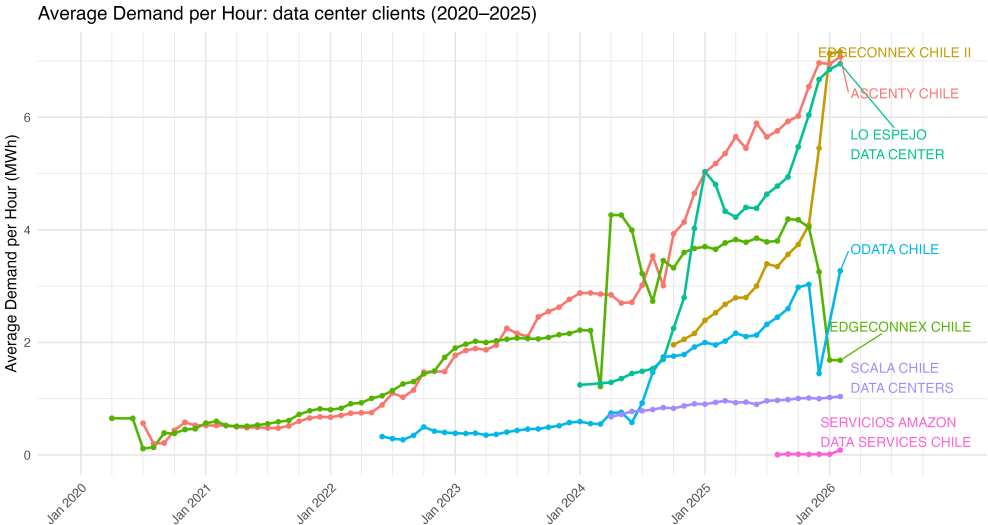
# Bonus

# Data center demand



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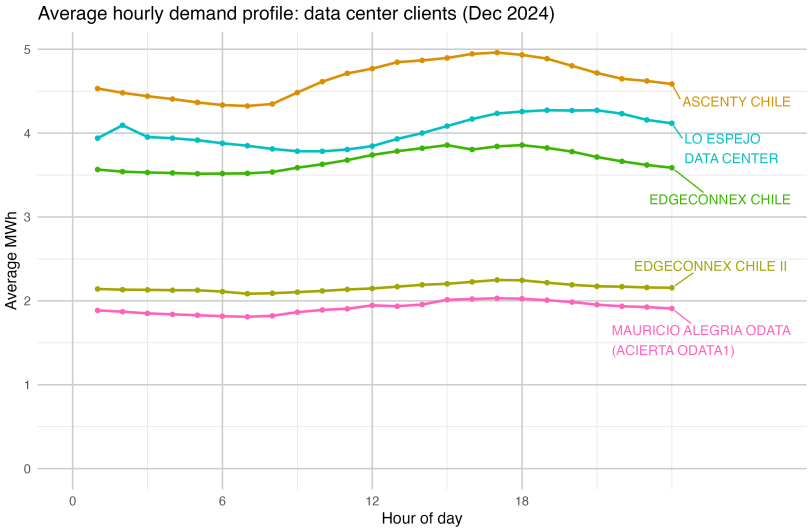

Thank you!

# Appendix