ELECTRICITY INTERRUPTIONS IN CHILE: CAUSES AND REGULATORY IMPLICATIONS

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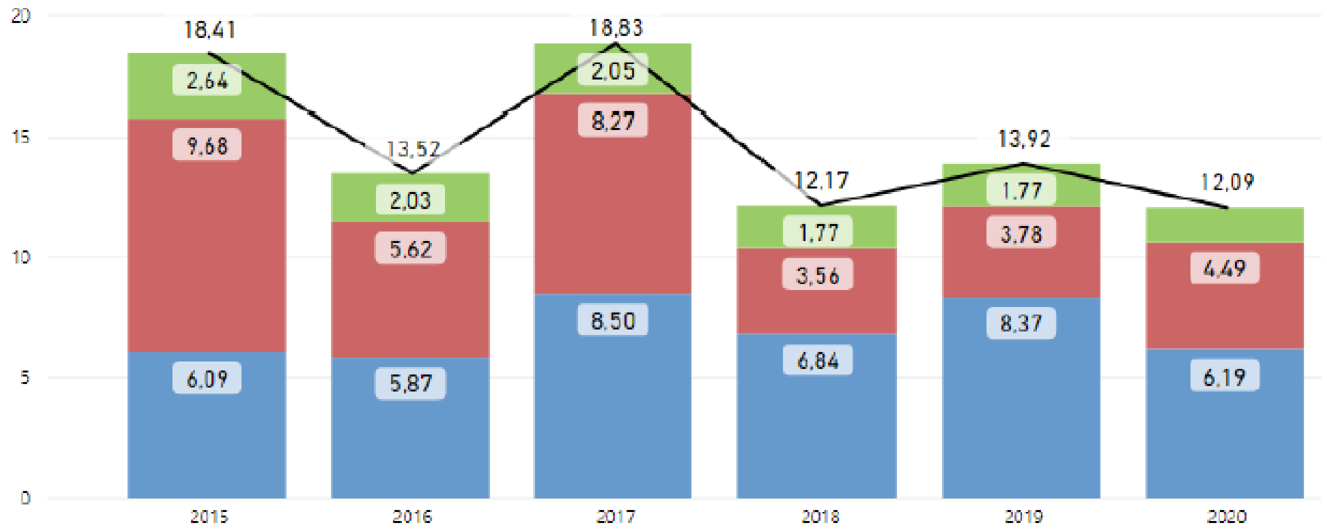
Introduction

- According to the World Energy Outlook 2020, 20% of total energy consumption in the world is based on electricity.
- The shift towards more electricity in the consumption mix has become a major source for emissions reductions.
- If the electricity sector is going to replace an important part of fossil fuel use with renewable electricity, one of the main issues will be the reliability of the electricity network.
- Understanding the reasons behind electricity outages it is important to address, not only a better quality of service for consumers but also to strengthen climate policies that promote electrification.

Introduction

- The issue of quality of supply and outages in electricity has different characteristics and challenges depending on the development of the country and the electricity network.
- In the case of Chile, having reached an electrification coverage of 99%, the challenge in recent years has focused on the quality of the electricity supply.
- With an average of 12 hours of electricity interruptions, Chile is far from other OECD countries, but below the average in Latin America.
- The Chilean Energy Policy aims to reach an annual average of 1 hour of interruptions per year by 2050 and 4 hours in 2035, without considering force majeure.



SAIDI (source: SEC Chile)

Related Literature

- Roberts and Rusell (2003) describe the key factors of power interruptions in two groups.
  - The inherited factors are derived from the differences that the distribution companies have inherited due to their long-term network design. For example, long overhead lines have a larger probability of faults than shorter and underground lines.
  - The inherent factors are related to the supply area in which a distribution company is serving. It includes differences in topographic, climatic, and demographic factors. For example, customers' density, weather conditions, etc.
- Campbell (2012) highlights that high winds, especially when combined with precipitation from seasonal storms, can cause damage to electricity utility systems, resulting in service interruptions to large numbers of electricity customers.

Related Literature

- The Chilean regulatory model in electricity distribution is a recurring reference in the literature. As Bustos and Galetovic (2007) mentions, <u>efficient-firm regulation</u> was conceived in the early 1980s, even before than the liberalization of the electricity supply industry started in UK.
- As Ajodhia and Hakvoort (2005) mention, there is empirical evidence that show that under rate-of-return regulation, existing reliability levels in the electricity industry are generally higher than optimal from a social point of view.
- However, at the same time they state that for capital-intensive industries like the electricity network business, a <u>stricter forms of price regulation are likely to lead to degradation in quality</u>. (Ajodhia, Schiavo and Malaman, 2006; Growitsch, Jamasb, and Pollitt, 2009; Ter-Martirosyan and Kwoka, 2010).

Data analysis

- To measure electricity interruptions, we use the System Average Interruption Duration Index (SAIDI). Monthly data from 2012 to 2018

$$SAIDI_j = \frac{\sum_i^N Clien_{fsi\_j} \cdot t_{i,c}}{Client_{inst\_j}}$$

- $Clien_{fsi\_j}$: Total number of clients connected to the distribution system in area j, that had suffered an interruption longer than 3 minutes that are a product of outages i, in a given period of time.
- $Clien_{inst\_j}$: Average total number of clients connected to the distribution system in area j, over the given period of time.
- N: Total number of interruptions in area j in a given period of time.
- $t_{i,c}$: Duration of interruptions of client c, longer than 3 minutes, as a result of outage i.

Data analysis

- Our database contains information on the source of the power interruption: due to force majeure, internal to the distribution system and external to the distribution system.
- This database contains SAIDI from 327 communes in Chile, but we can use only 220 communes with one distributor.
- In order to characterize the area of distribution, we estimate the participation of urban and rural clients in each commune
- To control for communal income, we use the average total income per capita in the household per commune
- For weather conditions, we obtained historical information from OpenWeather (https://openweathermap.org/)

Data analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
saidi_comunal	16,548	2.229	4.757	0	260.6
internal	16,548	0.852	1.692	0	98.25
Fm	16,548	0.998	3.793	0	259.23
External	16,548	0.378	1.565	0	51.27
Dx size	16,548	0.157	0.131	0.002	0.418
Income	16,548	260,893	158,086	80,561	1,855,463
Urban	16,548	0.691	.2938646	0	1

Variable	Obs	Mean	Std. Dev.	Min	Max
wind_40km	16,548	0.915	3.455	0	31
wind_50km	16,548	0.305	1.698	0	25
rain_1h_cri	16,548	3.316	4.193	0	24
rain_acum_cri	16,548	1.494	2.102	0	22
snow_1hs_cri	16,548	0.195	1.216	0	21
snow_ acum_cri	16,548	0.085	0.514	0	9

rain_1hs_cri: number of days in a month where the amount of rains was higher than the historical average of one hour (1992-2019) plus a standard deviation.

rain_acum_cri: number of days in a month where the amount of rains was higher than the historical average of one day (1992-2019) plus a standard deviation

Methods

- An econometric analysis has been carried out based on the following the empirical strategy based on Ter-Martirosyan and Kwoka (2010)
- As dependent variable we use the SAIDI indicator, separating in interruptions due to failures in generation-transmission (external) and distribution (internal), as well as by force majeure (FM).
- As explanatory variables we use indicators of income, urban-rural relationship, characteristics of distribution companies and geographic/climatic conditions.
- Also, in order to estimate the effect of regulation on power interruptions, we will consider differences between communes with distribution companies that have being the referential firm in the tariff setting processes with respect to other companies.
- Fixed effect by commune (according to Hausman test)

Results: Basic model

VARIABLES	Internal SAIDI	External SAIDI	FM SAIDI
Log communal income	-0.00094	-0.422***	0.369*
	(0.0738)	(0.0700)	(0.170)
Dummy for Winter months	0.152***	0.0248	0.539***
	(0.0251)	(0.0238)	(0.0577)
Dx size	-0.164	0.0138	-1.177**
	(0.156)	(0.148)	(0.359)
% Urban population	-0.292	-0.240	-0.0674
	(0.224)	(0.212)	(0.515)
Constant	1.028	5.752***	-3.562
	(0.908)	(0.861)	(2.086)
Obs.	16,548	16,548	16,548
Number of communes	197	197	197

* p<0.05, ** p<0.01, *** p<0.001

Income level is not significant for outages due to distribution networks, but it is for FM and outages from Gx and Tx.

Larger Discos handle better FM interruptions.

Results: Weather conditions

VARIABLES	Internal SAIDI	Internal SAIDI
Log communal income	0.0129	0.00663
	(0.0738)	(0.0737)
Dx size	-0.169	-0.166
	(0.156)	(0.156)
% urban population	-0.311	-0.312
	(0.224)	(0.224)
Nº days with high wind (40km/h)	0.0419***	0.0419***
	(0.00779)	(0.00775)
Nº days with critical rain hours	0.0218***	
	(0.00431)	
Nº days with critical snow hours	0.0465***	
	(0.0135)	
Nº days with critical cummulative rain hours		0.0415***
		(0.00699)
Nº days with critical cummulative snow hours		0.120***
		(0.0300)
Constant	0.815	0.902
	(0.909)	(0.907)

* p<0.05, ** p<0.01, *** p<0.001

- Weather factors are highly significant
- Cummulative snow and rain are marginally more important than hourly precipitations.

Results: Regulatory impacts

VARIABLES	Internal SAIDI	Internal SAIDI
Log communal income	-0.0358	-0.0411
	(0.0758)	(0.0758)
Dx size	-3.256	-3.315
	(2.455)	(2,454)
% urban population	-0.274	-0.275
	(0.224)	(0.224)
Nº days of high wind (40km/h)	0.0424***	0.0423***
	(0.00779)	(0.00775)
Nº days with critical rain	0.0220***	0.0417***
	(0.00431)	(0.00699)
Nº days with critical snow	0.0465***	0.119***
	(0.0135)	(0.0300)
Dummy reference firm	-0.513**	-0.513**
	(0.159)	(0.159)
Dx Size * reference firm	3.947	4.010
	(2.518)	(2.517)
Typical area number	-0.0223	-0.0198
	(0.0489)	(0.0489)
Constant	1.734	1.803
	(1.001)	(1.000)

* p<0.05, ** p<0.01, *** p<0.001

- Reference firms have lower level of interruptions, independently of their size.

Summary

- Besides demographic or geographic considerations, weather factors as well as regulatory design have a relevant effect of quality of supply when we look at outage hours.
- Force majeure interruptions are better handled by larger distribution companies.
- Income level by commune is not relevant to explain outages due to distribution reasons, but it is for interruptions in transmission-generation.
  - When there is a transmission or generation problem, the magnitude of the outage can be large. It is possible than lower income communes are more vulnerable to these kinds of events.

Summary

- Since referential firms have a better record in terms of quality of service, increasing the amount of referential firms can have a positive effect in quality of supply.
  - However, it is also possible that referential firms are chosen by the regulator because of the quality of information they can have on this firm in order to set tariffs.
  - If this is the case, firms with better quality of information (for tariffication) can be correlated with firms with better quality of service.

- One limitation of our analisys is that we could not account for all the communes in Chile, since there was no record of SAIDI per commune per distributor before 2018.
- In future research it will be interesting to consider a larger sample of communes and firms, for example cooperatives, and how they compare with the rest of the distribution sector in terms of quality of supply.

Thank you!