Residential Electrical Energy Consumption Profile in Brazil

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Overview - the Brazilian Economy post -1994

- Brazilian government started in June 1994, and economic plan (named "Plano Real") that dramatically reduced monthly inflation from 80% to about 1%.
- Before the advent of "Plano Real", lower income classes had no protection against daily inflation and currency devaluations, since they had limited access to baking services and products.

Overview - the Brazilian Economy post -1994

- At the onset of "Plano Real", minimum wage almost doubled in real terms (from roughly US$ 60 to US$ 100 monthly).
- The radical fall in inflation rates also contributed to increase, in real terms, the disposable income of poor families, since now their money has the same purchasing power at the beginning or at the end of the month.

Overview - the Brazilian Economy post -1994

- This, together with a stable currency, caused a massive income transfer to the poorest individuals in society.
- Even though credit restrictions have been imposed by Brazil's Central Bank and interest rates are among the highest in the world, access to credit is relatively easy, especially in the electronic goods and automotive sectors.

Overview - the Brazilian Economy post -1994

- All of these factors, together with increasing electronics imports, caused a substantial impact on electrical energy consumption, especially in the residential sector.
- Electricity rates (which are still under government control) have been raised above inflation rates, but this has not prevented consumption from experiencing unprecedented growth.

Overview - the Electric Sector in Brazil

- Most of the power plants are hydroelectric plants, whose construction takes a very long period of time (around 10 years, in some cases).
- The electric sector in Brazil has been going through dramatic changes since 1995.
- State controlled companies (energy producers and distributors) are being sold to private groups.

Overview - the Electric Sector in Brazil

- The explosive growth in electrical energy consumption in Brazil for the past 3 years has made demand analysis fundamental for planning and control.
- Several efforts are currently being made to create a residential consumer profile in different areas of the country.

Overview - the Electric Sector in Brazil

- A survey on residential electricity consumption habits and holding of electrical appliances was done in 1988.
- Due to technological advances and the economic changes just mentioned, this 1988 research is obviously outdated.

Overview - the Electric Sector in Brazil

- This presentation is part of an ongoing consulting project developed for Eletrobrás, the Brazilian Electric Sector Holding Company.
- The objective of this project is to create a profile of residential consumers in all areas of Brazil.

Overview - the Electric Sector in Brazil

- This profile will be able to identify electricity spending habits and aid in the implementation of Demand Side Management (DSM) policies.
- Effective implementation of DSM policies is crucial at this moment, since Brazil is on the verge of an electrical energy collapse, due to unexpected and unprecedented consumption growth.

Overview - the Electric Sector in Brazil

- Currently, we are in the process of implementing surveys throughout Brazil.
- Residential consumption is a major concern for electrical power companies in Brazil, since its share in total consumption has been growing fast since 1990.

Overview - the Electric Sector in Brazil

- In 1990, residential consumption corresponded to 20% of total electrical energy consumed.
- In 1996, this participation grew to 27%, and in the years 2000-2002, it is estimated at 33%.

Overview - the Electric Sector in Brazil

- The sample surveys currently in progress are important for two reasons:
  - Demand Side Management
  - Identification of factors that can serve as explanatory variables in forecasting models for residential consumption

Sampling Scheme used in the survey

- Due to the diversity in social and economic indicators throughout the country, an ordinary sample plan based on the number of residential consumers in each town or city is not appropriate, even when analyzing individual states.
- We propose an alternative sampling plan, where stratification is based on clustering.

Sampling Scheme used in the survey

- These clusters are created from the notion of an "electrical distance" which compares consumption in each town with average values for each utility company.
- These clusters will serve as strata in a stratified sampling procedure, in order to reduce "within stratum" variance.

Available Data for each town or city

- Total consumption
- Average household consumption
- Total number of households whose average monthly consumption falls into each of the 10 categories: 0-30 KWh, 31-50 KWh, 51-100 KWh, 101-150 KWh, 151-200 KWh, 201-300 KWh, 301-400 KWh, 401-500 KWh, 501-1000 KWh, above 1000 KWh.

We construct some additional variables, namely :

- Standardized Consumption = total town consumption standardized so that the whole sample of towns in each state is a variable with mean zero and variance one.
- Electrical Distance = Euclidean distance computed from the percentages of households in each category for a give town (in comparison with percentages for the entire state).
- Percentages of households in each of the 10 consumption categories.

Cluster Analysis

- Based on percentages of households in each of the 10 categories.
- We start the procedure by forming n clusters, where n is roughly 10 % of the number of towns in the state.
- Algorithm used: Euclidean distances, single linkage clustering.

Case Study: COELCE

- COELCE is the energy distributor in the State of Ceará, in the Northeastern part of Brazil.
- This clustering procedure is applied to all towns in the State, except for the capital city (Fortaleza), which was subject to a separate survey.
- Most towns and villages in the state are characterized by very small average electricity consumption.

Case Study: COELCE

- We start by forming 18 clusters, but several of those contained less than 3 towns or villages.
- Thus, a sampling procedure based on each of these clusters would not be cost-efficient, which lead us to reduce the number of clusters used.
- This reduction is done until each cluster formed contains a “reasonable” number of towns.

Case Study : COELCE

- In COELCE's case we used 10 clusters, but 6 of those consisted on 3 or less towns, and were later condensed in 2 new clusters.
- Moreover, the total number of households in these small clusters is negligible, and their combination doesn't lead to significant losses in precision.

Case Study : COELCE

10 Clusters based on percentages of households in each category

Cluster	num_obs	average consumption	std. dev.	average distance	std. dev.
1	50	55.1	4.2	0.22	0.03
2	22	51	3.9	0.27	0.03
3	1	45.9	******	0.31	******
4	3	60.7	1.5	0.2	0.01
5	4	67	7	0.17	0.04
6	63	68.1	5.6	0.14	0.03
7	23	87.4	6.9	0.07	0.02
8	2	72	0.21	0.14	0
9	3	43.2	2.5	0.35	0.01
10	3	38.8	3.3	0.41	0.03

ENTIRE SAMPLE	num_obs	average consumption	std. dev.	average distance	std. dev.
	174	63.6	13	0.18	0.08

Case Study: Rio de Janeiro

- We conducted a preliminary study in the city of Rio de Janeiro.
- The basic aim was to identify similar electricity consumption patterns among 154 neighborhoods that comprise the city.
- Originally, the city was divided into five zones using a geographical criterion.
- Significant differences among each of the five zones are observed.

5 geographical zones

- South (19 neighborhoods) - most affluent, but includes some shanty towns with totally different consumption patterns.
- North (26 neighborhoods) - some areas are upper medium class, but generally lower consumption than on the south zone.

5 geographical zones

- **West** (26 neighborhoods) - mixed, some new residential areas but others with rural characteristics.
- **Suburban** (71 neighborhoods) - low income areas, low energy consumption.
- **Center** (15 neighborhoods) - around downtown, some low income neighborhoods.

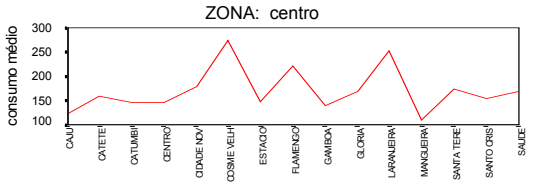
Descriptive Statistics - whole sample

	average	std.dev.	minimum	maximum
consumption	192.1	54.8	97	492
p0-50	13.9	5.6	5.0	33.9
p51-100	17.6	5.3	3.4	32.0
p101-150	19.2	3.9	6.9	26.7
p151-300	34.5	6.9	13.4	48.8
p301-500	10.6	5.3	1.9	29.2
p>501	4.2	6.3	0	52.6

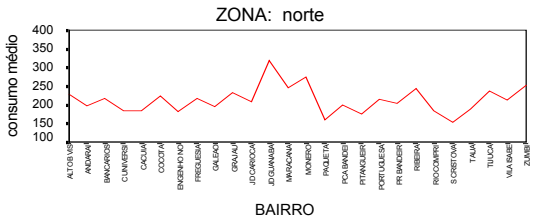
Case Study : Rio de Janeiro

- We consider only 6 categories of energy consumption, namely:
  - 0-30 KWh
  - 31-50 KWh
  - 51-100 KWh
  - 101-150 KWh
  - 151-300 KWh
  - 301-500 KWh
  - above 501 KWh

Average Consumption by zone

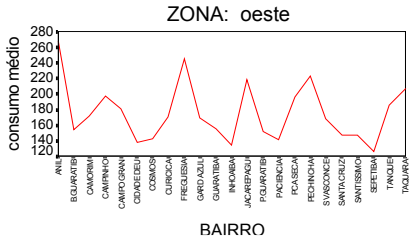


Center

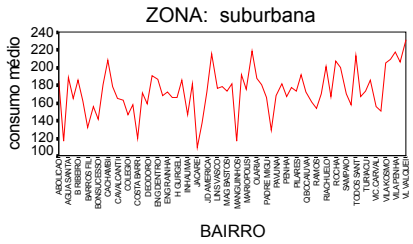


North

Average Consumption by zone

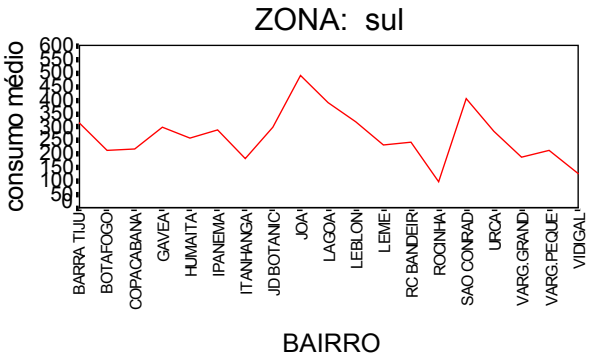


West



Suburban

Average Consumption by zone



South

Cluster Analysis of neighborhoods

- We base the cluster procedure on the percentages of households in each of the 6 energy consumption categories.
- We created 12 clusters, of which 6 contain only one neighborhood.
- 2 other clusters contain 2 neighborhoods each.

Cluster Analysis of neighborhoods

Cluster	# obs.	average consumption	std.dev.	average % above 301 KWh	average % below 151 KWh
11	1	97.0	****	2.4	84.3
2	8	118.8	6.5	4.0	75.1
4	28	149.3	11.1	7.3	64.0
9	2	175.0	19.8	15.4	60.3
5	1	186.0	****	16.1	66.9
1	99	192.7	24.8	14.1	47.5
10	1	246.0	****	27.1	46.6
8	2	265.0	15.6	29.2	25.1
3	9	297.0	19.1	36.9	31.8
7	1	391.0	****	55.6	16.8
12	1	408.0	****	56.1	24.7
6	1	492.0	****	64.9	19.8
Whole Sample	154	192.1	54.8	14.8	50.7

Conclusions

- In both cases, the clustering procedure results in groups that are much more homogeneous than the entire sample.
- In the Rio de Janeiro case study, even in cluster 1, which contains roughly 2/3 of the sample, there is a considerable reduction of variance, when compared with the whole sample of neighborhoods.

Conclusions

- Moreover, some of the neighborhoods singled out by the cluster procedure are clear “outliers”, that is, do not represent the entire population being sampled.
- In the Rio de Janeiro case study, clusters 6, 7 and 12 represent very high income areas of the city, as reflected by their energy consumption levels.

Conclusions

- Also, cluster 11 indicates the neighborhood with lowest average consumption among all 154 sampled.
- Surprising as it might be, clusters 6 (highest average consumption) and 11 (lowest average consumption) are geographically contiguous.