# Zipf is back in town. Spatial distribution and energy inequality of African cities

#### Enrico Lippo

Fondazione Eni Enrico Mattei -FACTS research group-

September 24, 2019

- evolution of top 10 African cities
- urban population from 1960 to 2015
- mapping urban population
- 2 Urban concentration
  - concentration indices
  - the Zipf's coefficient
  - mapping urban concentration and its dynamics
- 3 Ongoing research: concentration and access to electricity
  - Electrificapolis: mapping urban access to electricity
  - Spatial inequality in electricity access
  - Electricity Gini: an index to measure inequality in electricity consumption



Enrico Lippo (FEEM)

Workshop-Urban Africa

September 24, 2019 3 / 21



Enrico Lippo (FEEM)

Workshop-Urban Africa

September 24, 2019



Enrico Lippo (FEEM)

Workshop-Urban Africa

September 24, 2019 5 / 2



Urban population is expected to reach 1.5 billion in 2015, reaching 60 % of the total African population [World Urbanization Prospects, UN (2018)]

Enrico Lippo (FEEM)

Workshop-Urban Africa

Percentage of urban population by African countries Data: Africapolis (2015)



Many indices to measure urban concentration

- Urban primacy: % of the population living in the largest city
- Share of population living in big cities: threshold required
- Herfindahl-Hirschman-index (HHI): concentration index
- **Zipf's law**: empirical phenomenon in which the size of a country's cities follows a Pareto distribution

The first two indicators are not a good measure of the full urban structure Thanks to Africapolis, we can use the last two indicators We select the Zipf's coefficient:

- easy to estimate (OLS)
- provides confidence intervals

#### Urban concentration-Zipf's law

Empirical phenomenon in which the size of a country's cities follows a Pareto distribution:

$$POP_{i} = \left(\frac{POP_{first}}{RANK_{-}SIZE_{i}}\right)$$
(1)

the second largest city within a country is half the size of the largest, the third largest city has a third of the population of the largest city and so forth.

It can be tested regressing the log of the population of all cities on the log of the cities' rank:

$$\ln(POP_i) = \beta_0 + \beta_1 \ln(RANK_-SIZE_i) + \varepsilon_i$$
(2)

If  $\hat{\beta} = -1$ , then the it holds:

$$E(\ln(POP)|RANK_{-}SIZE) = \hat{\beta}_{0} - \ln(RANK_{-}SIZE_{i})$$
(3)

## Zipf's law- examples

Graphically, if the city size distribution follows Zipf's law, a straight downward line with a slope of -1 emerges



Enrico Lippo (FEEM)

September 24, 2019

10/21

### Zipf's law- examples

#### Very uneven distribution



#### Very even distribution



#### Zipf's law- examples



$$\hat{\beta}_{ANGOLA} = -1.34$$
  
 $\hat{\beta}_{TCHAD} = -0.79$ 

Enrico Lippo (FEEM)

September 24, <u>2019</u>

12/21

#### Urban concentration

Zipf's coefficient for 2015 (absolute values) Data: Africapolis



э

#### Urban concentration

Percentage growth of the Zipf's coeffcient from 2010 to 2015 Data: Africapolis



э

#### Data

- gridded dataset of 1 km resolution
- developed in partnership with IIASA (International Institute for Applied Systems Analysis)
- satellite data are used to observe lighting during daylight and (mostly) night-time
- diffusion of electrification and density of population in each year between 2014 and 2018
- estimate of the average level of electricity consumption for 2018
- an useful reference is Falchetta, Pachauri, Parkinson & Byers (2019)

## Access to electricity: an application to Ethiopia



## Application 1: Electrificapolis

#### Addis Ababa



Addis Ababa is the capital and the first city of Ethiopia It has a population of about 3.7 million inhabitants Completely electrified (yellow cells cover all the city map)

## Application 1: Electrificapolis

#### Harar



Harar is the fourth urban agglomeration of Ethiopia.

It is located in the east of the country and it has a population of about 450,000 inhabitants.

Not completely electrified (red points within the city area): the electricity access rate is estimated at 81.7%

## Application 2: Spatial correlation in electricity access



- electricity access is computed for each Ethiopian district (woreda)
- contiguity matrix to match each district with its k neighbours
- Moran's I to measure spatial inequality in electricity access

## Application 3: Electricity Gini



- information on the average electricity consumption in 2018 is used
- tiers: (1) <0.2 kWh/day/household; (2) <1 kWh/day/household; (3) <3.4 kWh/day/household; (4) >3.4 kWh/day/household
- each 1km x 1km grid is linked with information on population and electricity consumption
- a Gini index and the associated Lorenz curve are computed

Enrico Lippo (FEEM)

## "Thank You"



Enrico Lippo (FEEM)

Workshop-Urban Africa

-September 24, 2019 21/21

Image: Image:

э