Universality Laws in Commuting Flows

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Universality laws in commuting flows

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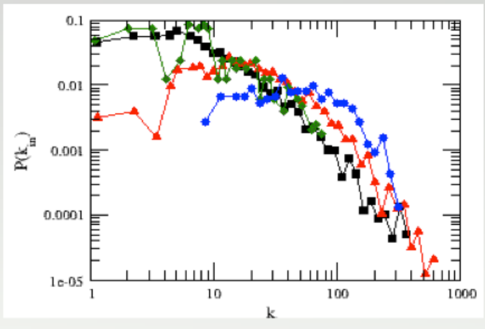
We propose an individual based model to generate commuting networks from data giving numbers of in and out commuters of every locations of a region. It is inspired from the gravity model. We exhibit from the calibration of 80 various case studies that the only remaining parameter can be suppressed since it follows a law depending on the average surface of the locations. We compare our model to the only one other universal existing approach (Simini et al, 2012) at various scales. We show our model performs better for small locations (in terms of surface and/or number of inhabitants).

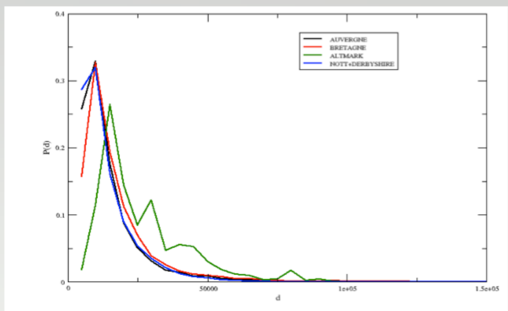
Commuting networks

Daily (weekly) flows of people travelling from a place of residence to a different working place.

This phenomenon concerns half of the world population!!!



NO PARTICULAR TOPOLOGICAL PROPERTIES



Particular properties concerning the spatial embedding:
TYPICAL DISTANCES AROUND 20-50 km

The modeling approach

Why do we need models?

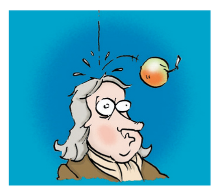
FROM AVAILABLE AGGREGATE DATASETS:

- Total number of in-commuters (s^{in})
- Total number of out-commuters (s^{out})

TO ORIGIN-DESTINATION TABLES

From \ to	M1	M2	M3	M4	…
M1	0	4	8	15	…
M2	24	0	12	4	…
M3	3	5	0	7	…
M4	1	0	20	0	…
…	…	…	…	…	0

Gravity model:



The traffic of commuters between two places I and J depends on:
- population of the residence place,
- population of the working place,
- distance between the two places

$$T_{I \to J} = \frac{N_I^{\alpha} N_J^{\gamma}}{f(d_{IJ}, \beta)}$$

Problems:

1- Lack of a rigorous derivation (what is the form of the deterrence function?)
2- Many parameter to calibrate not associated to any geographical or social characteristics of the case study
3- $P(N_I, N_J | r_{IJ})$ is very broad
4- T_{IJ} is not limited by N_I
5- It is deterministic

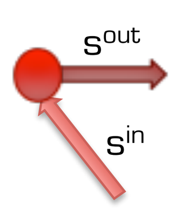
A new individual based morphogenetic model

All the individuals make a compromise between the job offer in each location and the distance between the residence and the location.

To each node are associated:

1-s^{out} individuals looking for a job(out-commuters)

2- s^{in} jobs available (in-commuters)



Temporal evolution

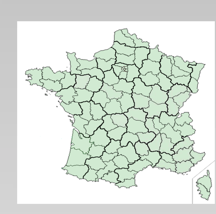
1- Random choice of a residence I place with at least one available out-commuter ($s^{out}_I > 0$)

3- Random choice of the working place with probability:

$$P_{I \to J} = \frac{s_J^{in} e^{-\beta d_{IJ}}}{\sum_K s_K^{in} e^{-\beta d_{IK}}}$$

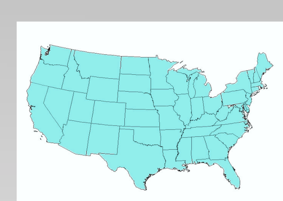
4- Update of the node quantities: s^{in}_J– , : s^{out}_I–

The Datasets

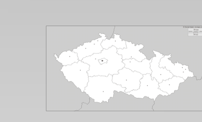


France
–Regions
–Cantons
–Municipalities

Italie
–Regions
–Provinces
–Municipalities

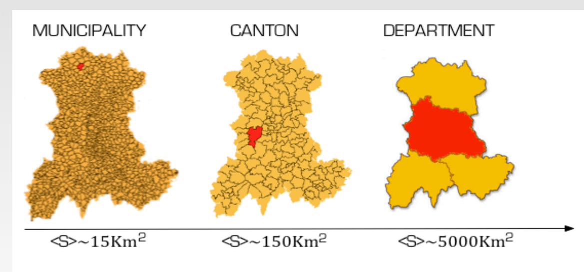


USA
–Counties



Tchech Republic
–Municipalities

Different granularity scales



The parameter follows an universality law that we have extracted from calibrated case studies

The calibration procedure

Calibration:
Calibration with the β minimizing the Kolmogorov-Smirnov distance between the real and the generated distance distribution

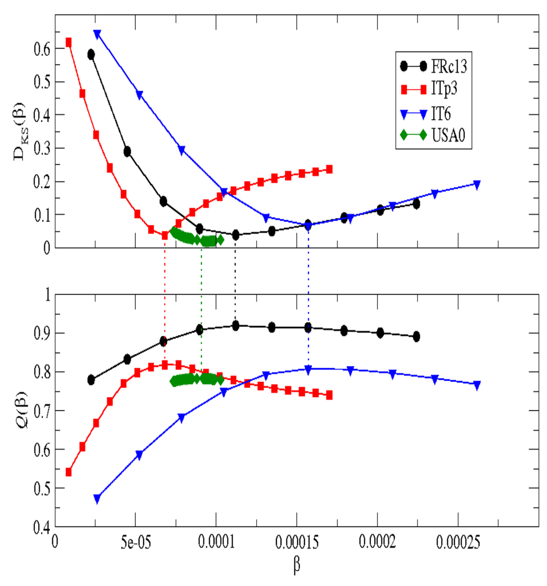
$$D_{KS}(\beta) = \sup_d |P^{REAL}(d) - P^{SIM}(d, \beta)|$$

Validation:
Common part of commuters (Sorensen index)

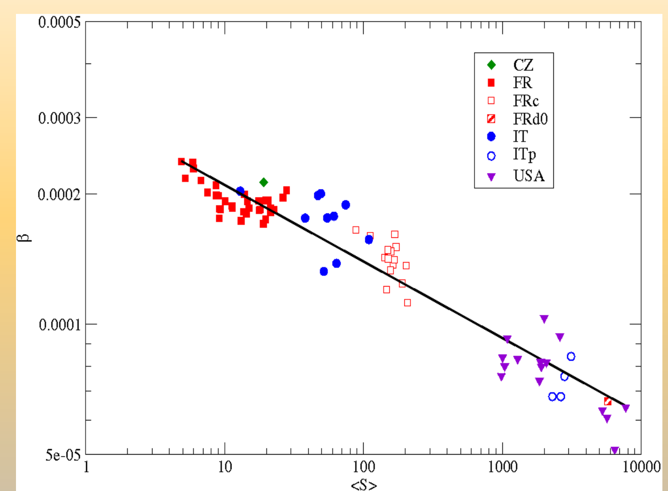
$$Q = \frac{2N_{REAL \cap SIM}}{N_{REAL} \times N_{SIM}}$$

$$N_{REAL \cap SIM} = \sum_{I=1}^{n+1} \sum_{J=1}^{n+1} \min(Y_{IJ}, \tilde{Y}_{IJ})$$

$$N_{REAL} = \sum_{I=1}^{n+1} \sum_{J=1}^{n+1} Y_{IJ} \qquad N_{SIM} = \sum_{I=1}^{n+1} \sum_{J=1}^{n+1} \tilde{Y}_{IJ}$$



UNIVERSALITY PROPERTIES OF THE PARAMETER



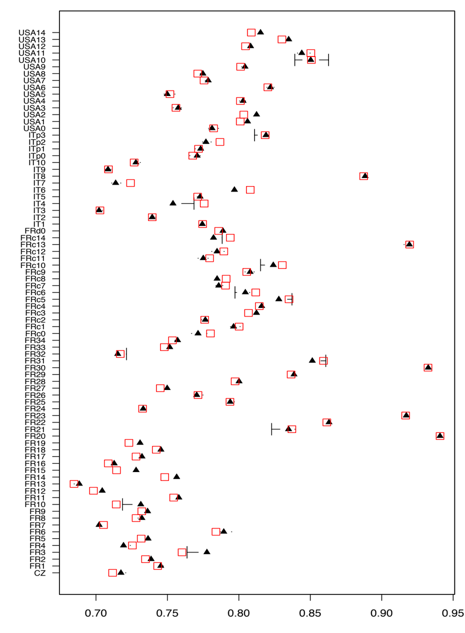
$$\beta = \beta^* < S >^{-\nu}$$

$$\beta^* = 0.000315 m^{-1}$$

$$\nu = 0.177$$

The parameter can be fixed in an endogenous way as a function of the average surface of the locations

A cross-validation test



Calibrated β value

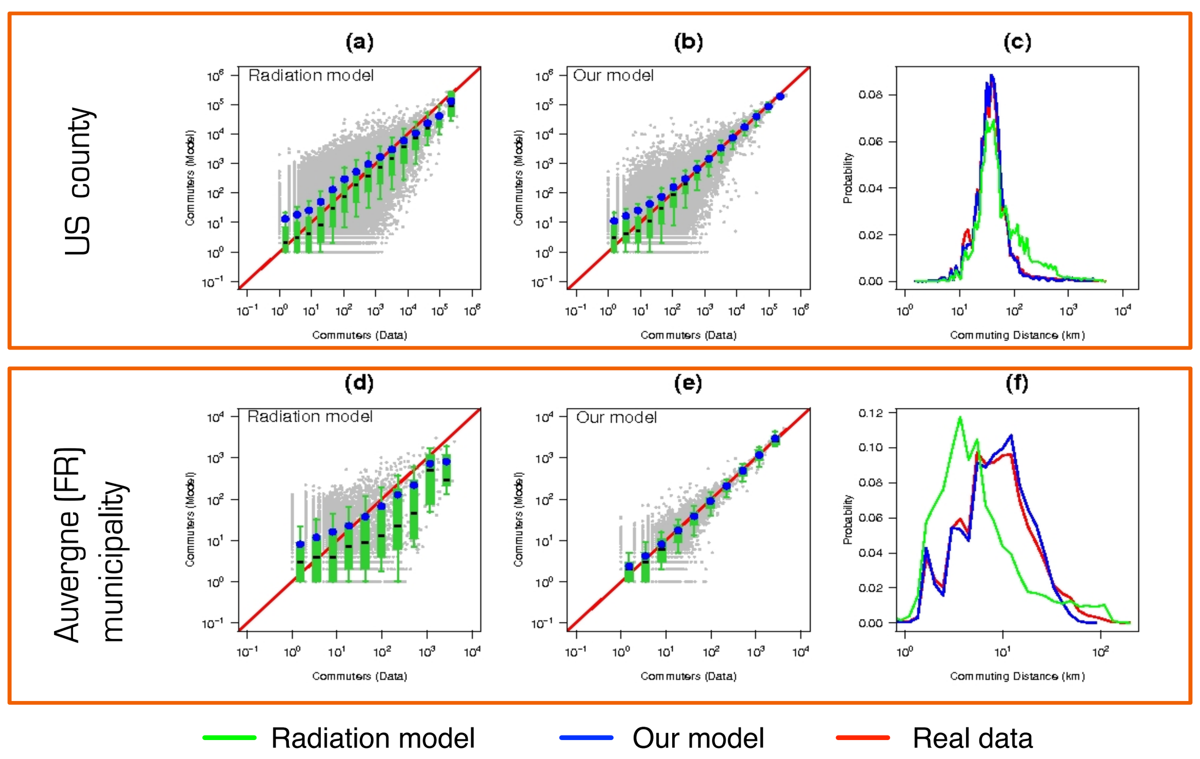
β obtained by the universality formula

Comparison with the radiation model

The traffic of commuters between two places does not depend directly on the distance but only on the cumulative population in a circle centered in the residence place (I) and with radius d_{IJ}

$$\langle T_{I \to J} \rangle = T_I \frac{N_I N_J}{(N_I + s_{IJ})(N_I + N_J + s_{IJ})}$$

Simini, F., M. C. Gonzalez, et al. (2012). "A universal model for mobility and migration patterns." Nature 000: 1-5.



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Prototypical impacts of multifunctional Activities in rural municipalities