A Macro-scale Model of Co-evolution for Cities and Transportation Networks

J. Raimbault[1,2]
juste.raimbault@polytechnique.edu

[1]UMR CNRS 8504 Géographie-cités
[2]UMR-T IFSTTAR 9403 LVMT

Medium 2017 Conference

Spatio-temporal Behavior in Complex Urban Systems

17th June 2017

New pathways for sustainable urban development in China's medium-sized cities

This Project is funded by the European Union

Systems of Cities and Transportation Networks

Co-evolution

Research Objective

$\rightarrow$ *introduce a simple but modular model of co-evolution of cities and networks at the scale of a system of Cities.*

Model : Rationale

- Cities represented by their population follow deterministic growth based on self growth (Gibrat) and interactions with other cities (similar to [?])
- Drivers of network growth are flow demands

Generic Model

Model : Abstract Network

Model : Physical Network

Results

Case studies

Conclusion

→

→

- All code and data available at
`https://github.com/JusteRaimbault/CityNetwork/tree/master/Models/MacroCoevo`

Reserve Slides

Model Formalization : Interactions

$\rightarrow$ Work under Gibrat independence assumptions, i.e. $\mathrm{Cov}[P_i(t), P_j(t)] = 0$. If $\vec{P}(t+1) = \mathbf{R} \cdot \vec{P}(t)$ where $\mathbf{R}$ is also independent, then $\mathbb{E}\left[\vec{P}(t+1)\right] = \mathbb{E}[\mathbf{R}] \cdot \mathbb{E}\left[\vec{P}\right](t)$. Consider expectancies only (higher moments computable similarly)

$\rightarrow$ With $\vec{\mu}(t) = \mathbb{E}\left[\vec{P}(t)\right]$, we generalize this approach by taking $\vec{\mu}(t+1) = f(\vec{\mu}(t))$

Model Formalization : Interactions

Let $\vec{\mu}(t) = \mathbb{E}\left[\vec{P}(t)\right]$ cities population and (d_{ij}) distance matrix

Model specified by

$$f(\vec{\mu}) = r_0 \cdot \mathbf{Id} \cdot \vec{\mu} + \mathbf{G} \cdot \mathbf{1} + \mathbf{N}$$

with

- $G_{ij} = w_G \cdot \frac{V_{ij}}{<V_{ij}>}$ and $V_{ij} = \left(\frac{\mu_i \mu_j}{\sum {\mu_k}^2}\right)^{\gamma_G} \exp\left(-d_{ij}/d_G\right)$
- $N_i = w_N \cdot \sum_{kl} \left(\frac{\mu_k \mu_l}{\sum \mu}\right)^{\gamma_N} \exp\left(-d_{kl,i}\right)/d_N$ where $d_{kl,i}$ is distance to shortest path between k, l computed with slope impedance $(Z = (1 + \alpha/\alpha_0)^{n_0}$ with $\alpha_0 \simeq 3)$

Model Formalization : Network Growth

Model Formalization : Indicators

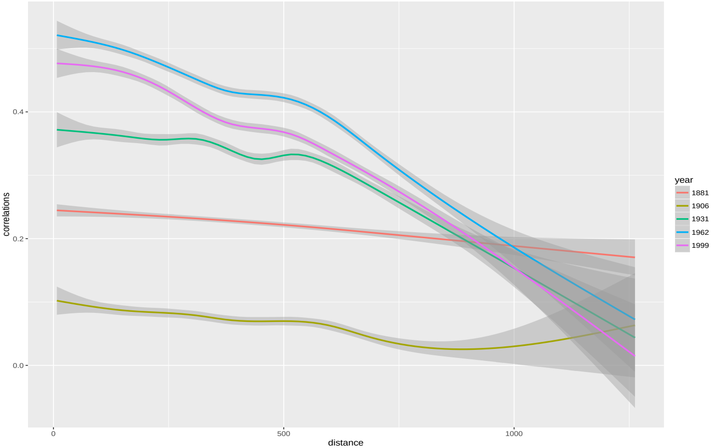
- Initial-final rank correlation (changes in the hierarchy) for variable X : $\rho\left[X_i(t=0), X_i(t=t_f)\right]$
- Trajectory diversity for variable X : with $\tilde{X}_i(t) \in [0;1]$ rescaled trajectories,

$$\frac{2}{N\cdot(N-1)}\sum_{i<j}\left(\frac{1}{T}\int_t\left(\tilde{X}_i(t)-\tilde{X}_j(t)\right)^2\right)^{\frac{1}{2}}$$

Data : stylized facts

Population data for French-cities (Pumain-INED database : 1831-1999)

Non-stationarity of log-returns correlations function of distance



References I