

# Modeling the Co-evolution of Urban Form and Transportation Networks

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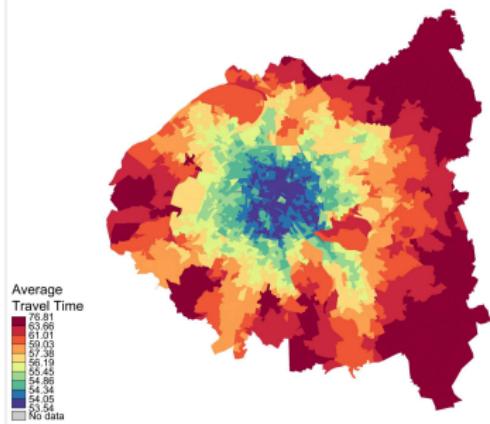
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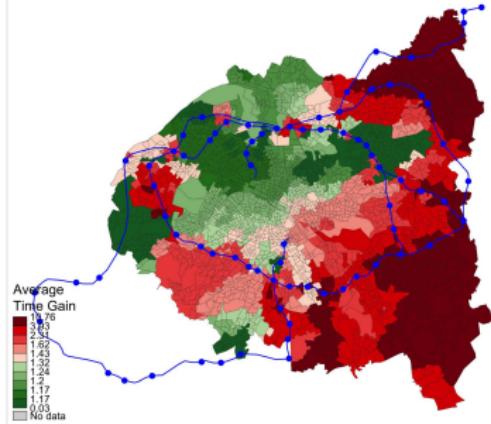
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# Circular Causalities in Complex Systems

Time Accessibility without GPE



Time Accessibility Gain



*Time accessibility gain allowed by GPE new lines*

# Causality in Geography

# Existing approaches

# Research objective

# Method: Rationale

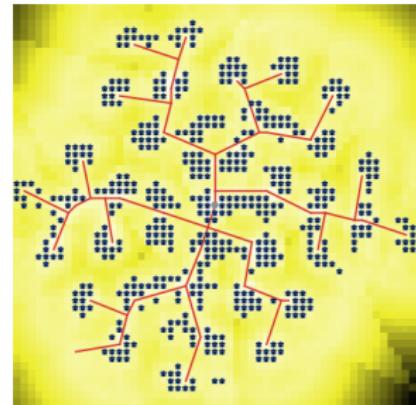
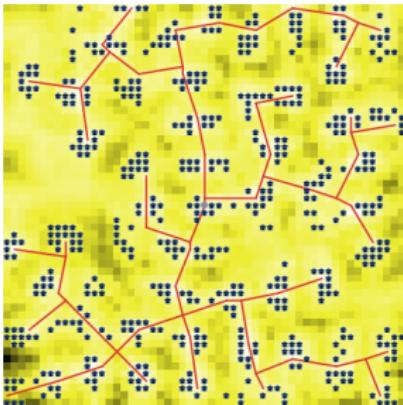
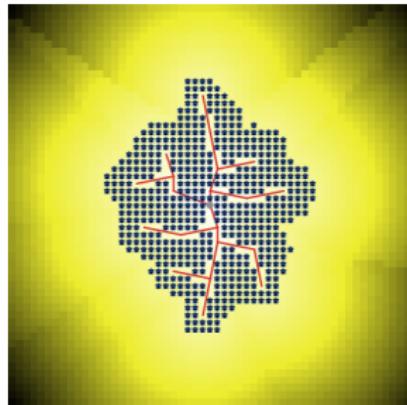
## Method: Formalization

Correlation estimator  $\hat{\rho}$  applying in time, space and repetitions, i.e.  
 $\hat{\rho}[X, Y] = \hat{\mathbb{E}}_{i,t,k}[XY] - \hat{\mathbb{E}}_{i,t,k}[X]\hat{\mathbb{E}}_{i,t,k}[Y]$

Lagged Correlation

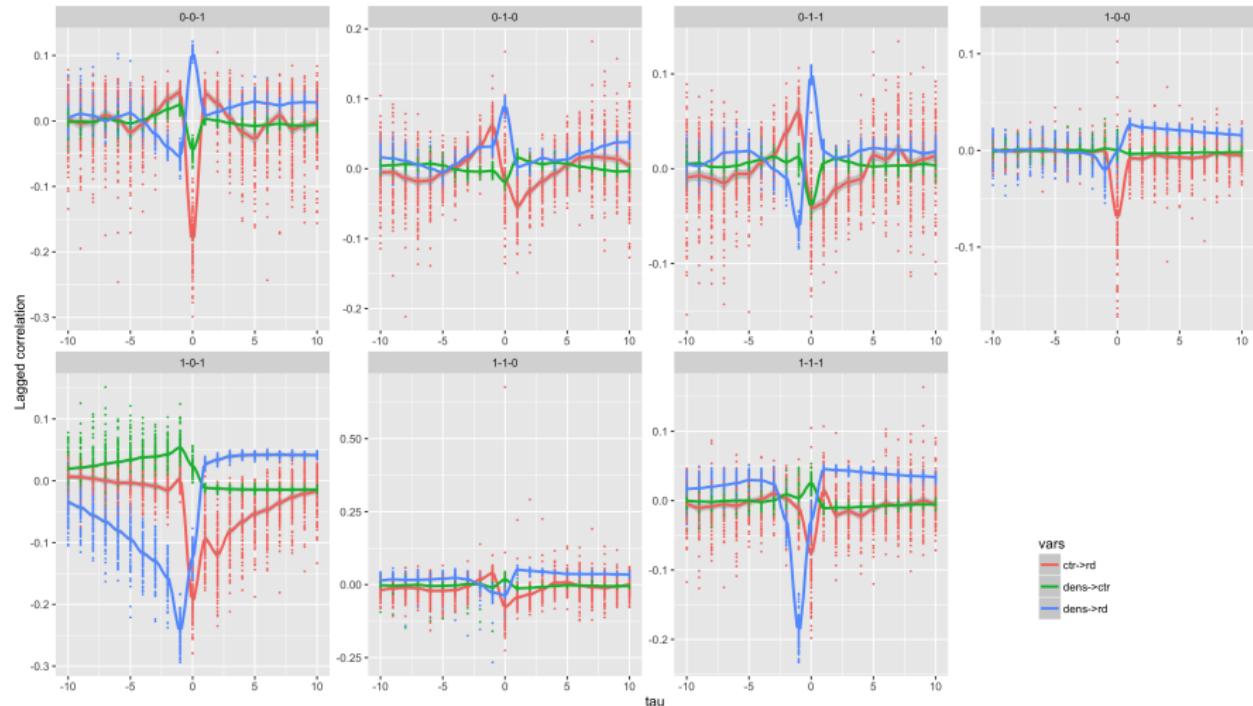
$$\rho_\tau[X_{j_1}, X_{j_2}] = \hat{\rho}\left[x_{i,j_1,t-\tau}^{(k)}, x_{i,j_2,t}^{(k)}\right] \quad (1)$$

## Validation: Synthetic Data



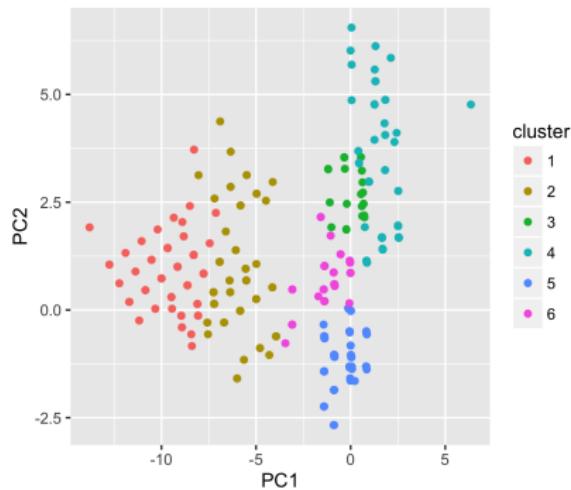
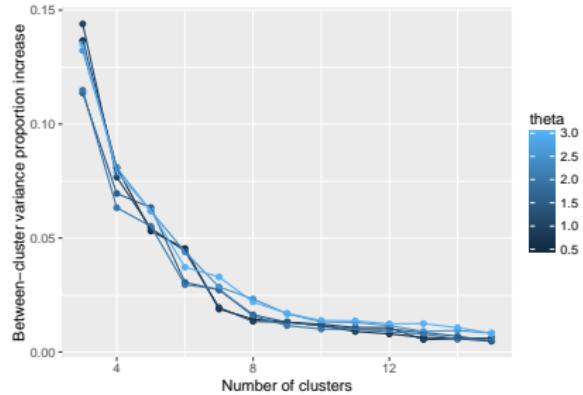
*Synthetic urban configurations generated by an hybrid morphogenesis model from [Raimbault et al., 2014]*

# Profiles of lagged correlations



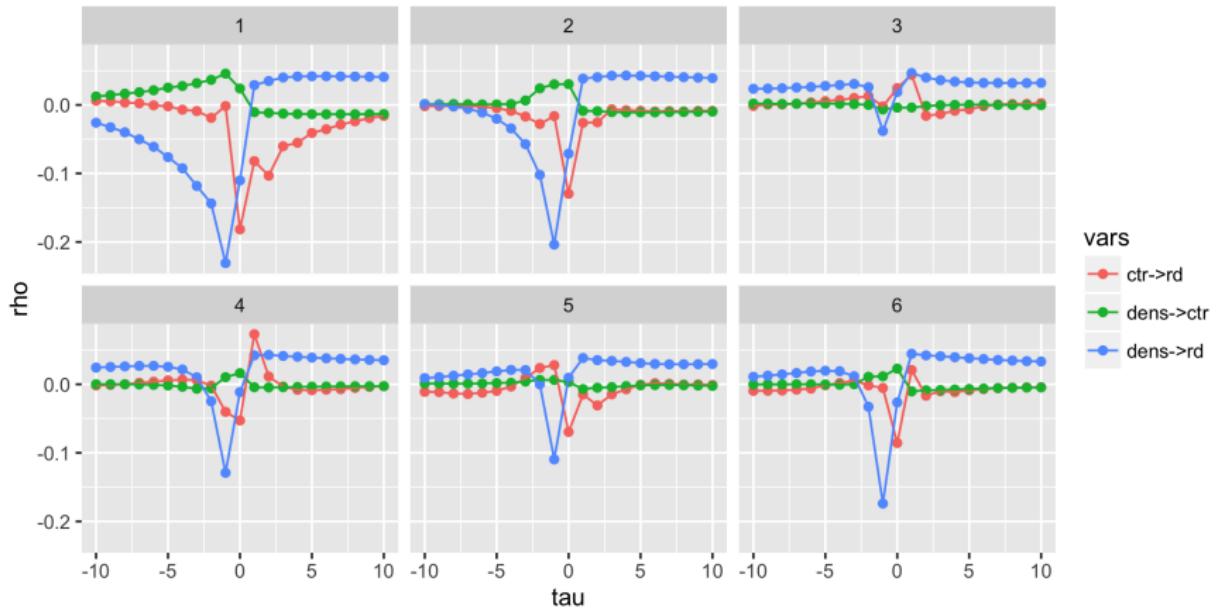
Values of  $\rho_\tau$  for all couples of three explicative variables (density, distance to center, distance to roads), for 8 extreme parameter points

# Unveiling Endogenous causality regimes



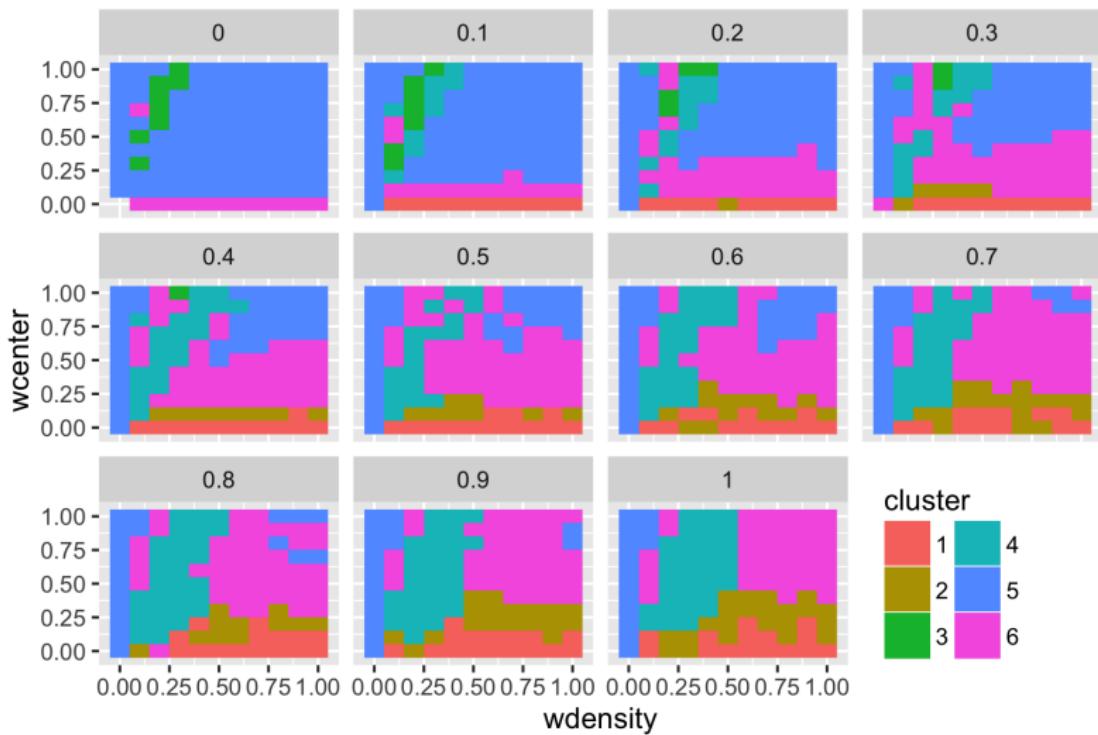
*Unsupervised classification (robust k-means) on  $\tau_{min}, \tau_{max}$  features:  
(Left) Derivative of clustering coefficient for number of clusters  $k$ ;  
(Right) PCA visualisation of classification for “optimal”  $k$*

# Consistence and interpretation of regimes



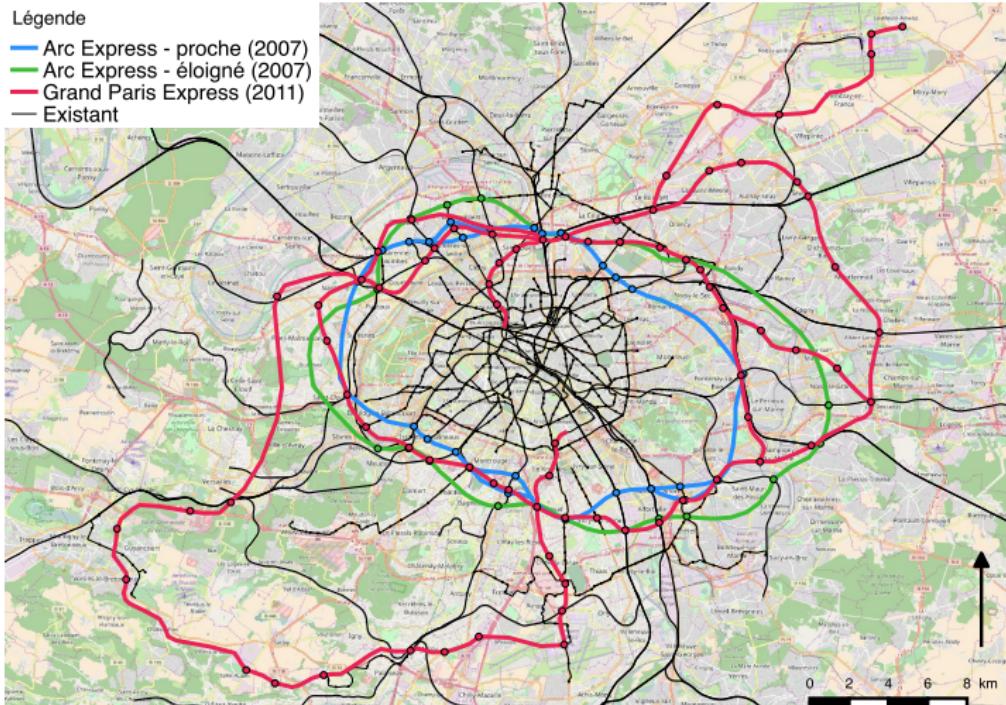
*Values of cluster centers in terms of  $\rho_\tau$*

# Consistence and interpretation of regimes



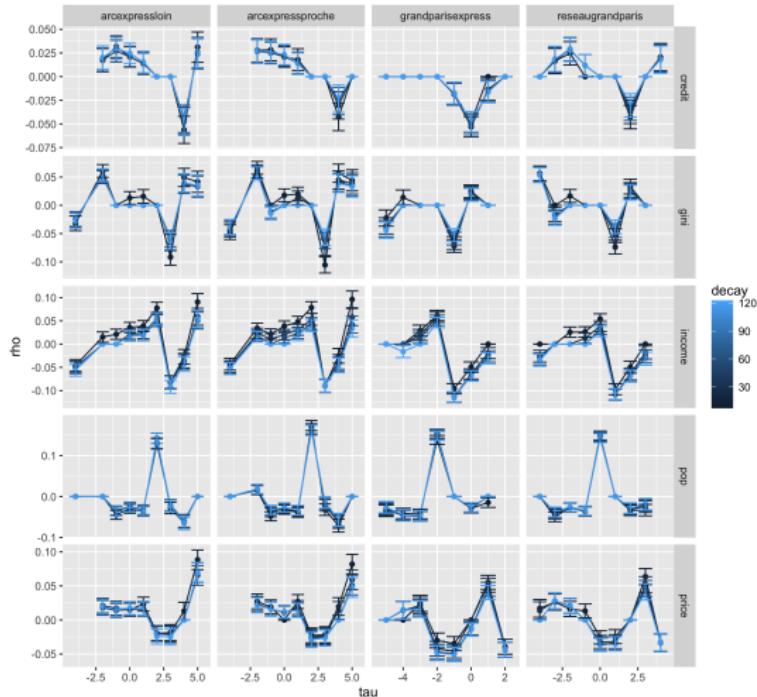
*Position of clusters in the parameter space  $w_i$*

# Application: Case study



*Successive projects for the Grand Paris new transportation infrastructure*

# Application: Results



*Values of  $\rho_\tau$  for the different projects (columns) and different variables (rows), with accessibility differentials*

# Discussion

## Implications

→

## Developments

→

# Conclusion



- Code, data and results available at  
<https://github.com/JusteRaimbault/CityNetwork>

Reserve slides

## Reserve Slides

## References I

-  Raimbault, J., Banos, A., and Doursat, R. (2014).  
A hybrid network/grid model of urban morphogenesis and optimization.  
In *Proceedings of the 4th International Conference on Complex Systems and Applications (ICCSA 2014)*, June 23-26, 2014,  
*Université de Normandie, Le Havre, France; M. A. Aziz-Alaoui, C. Bertelle, X. Z. Liu, D. Olivier, eds.*: pp. 51-60.