Agent-based Modeling of Migrant Workers Residential Dynamics within a Mega-city Region: the Case of the Pearl River Delta, China

Cinzia Losavio[1] and Juste Raimbault[1,2]
(1) UMR CNRS 8504 Géographie-cités and (2) UMR-T IFSTTAR 9403 LVMT

2017 INTERNATIONAL CONFERENCE ON CHINA URBAN DEVELOPMENT

5–6 MAY 2017 LONDON

(SESSION 6D MIGRANT SETTLEMENT DECISIONS)

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

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

MEDIUM is led by CNRS, hosted by Géographie-cités and co-financed by the European Union.
Scientific coordinator: Pr. Natacha AVELINE-DUBACH

- **PARTNERS :**
  COORDINATOR INSTITUTION: CNRS (France);
  4 CO-APPLICANTS : Hangzhou Normal University in China, Science Po Aix in France, Ca' Foscari University in Italy, Spatial Foresight GmbH in Luxembourg;
  2 ASSOCIATES IN SWITZERLAND: the universities of Lausanne and Neuchatel
- **THREE MEDIUM-SIZED CITIES**: Hangzhou, Zhuhai and Datong
- **OBJECTIVE**: to study the socio-economic and urban development dynamics
- **INTERESTS**: urban governance, strategic planning, urban mobility, inclusion of migrants, ICT or networks of multinational corporations.

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

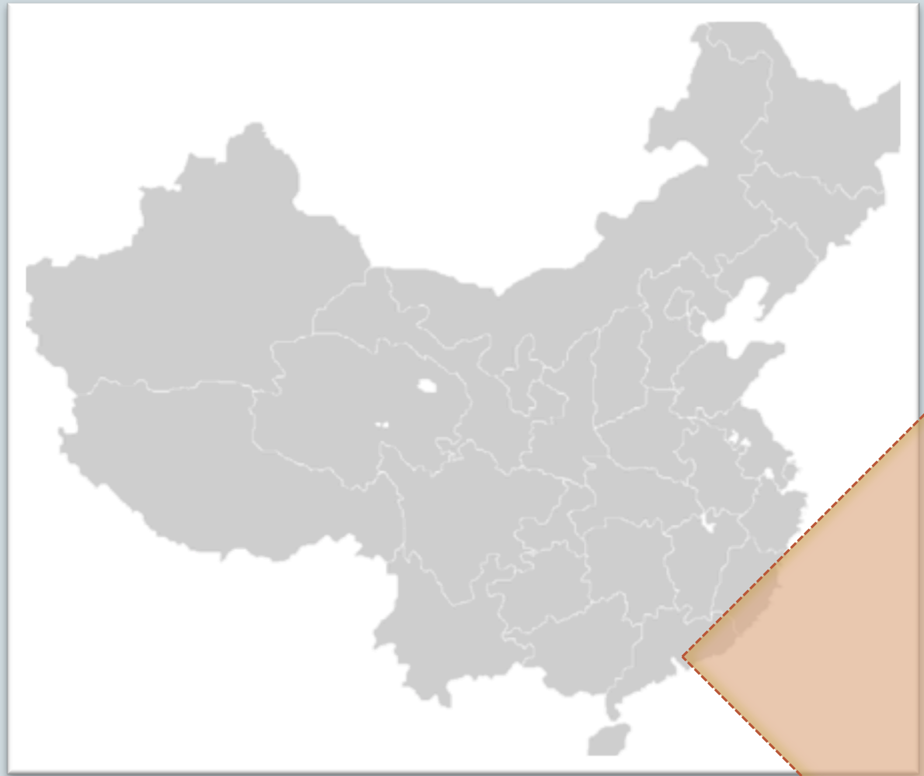
Mega-city regions

«*Mega-city regions (MCRs) are integrated sets of cities and their surrounding suburban hinterlands across which labor and capital can be reallocated at very low cost*» (Florida, Gulden & Mellander, 2008).

Main characteristics:

- Globally connected (Hall and Pain, 2006)
- Symbiosis between urban and rural areas
- Migration flows
- Density of connections
- Regional migration patterns (Mu and Yeh, 2016)

Pearl River Delta (PRD) : the most prosperous and dynamic mega-city region in terms of migration waves



Picture by Cinzia Losavio, 2016

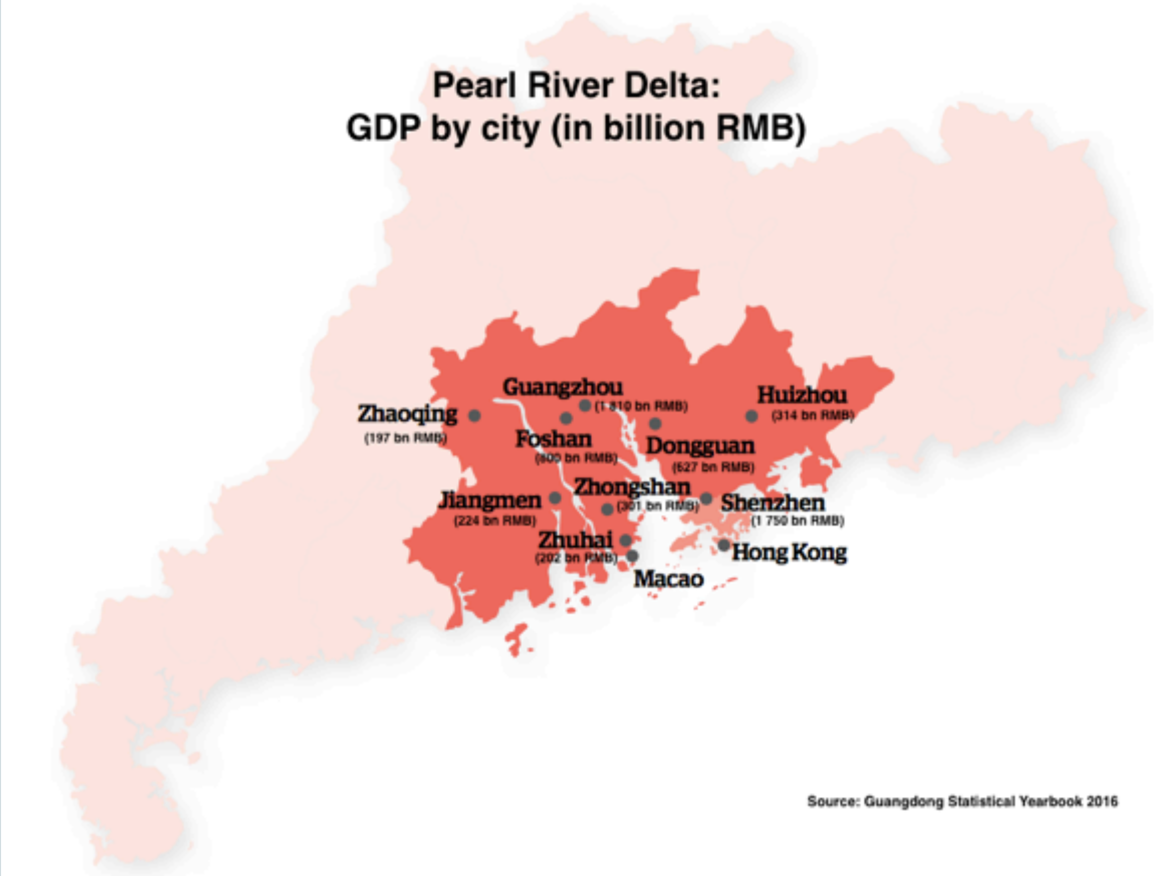
Source: Invest HK, 2010

PRD Mega-city region characteristics

In 2015, the PRD accounted for:

- ➢ 4.3% of China's total population
- ➢ 9.1% of China's GDP
- ➢ 26.8% of China's total export

Polycentrism



This agent-based model simulates migrants residential patterns taking into account the full range of migrants' socio-economical status

3 dimensions to discern migrant workers diversity

RESIDENTIAL

Picture by Cinzia Losavio, Zhuhai, 2017

GENERATIONAL

Picture by Cinzia Losavio, Zhuhai, 2017

PROFESSIONAL

Picture by Cinzia Losavio, Zhuhai, 2017

medium

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

Main qualitative lessons from baseline model exploration: qualitative interpretation

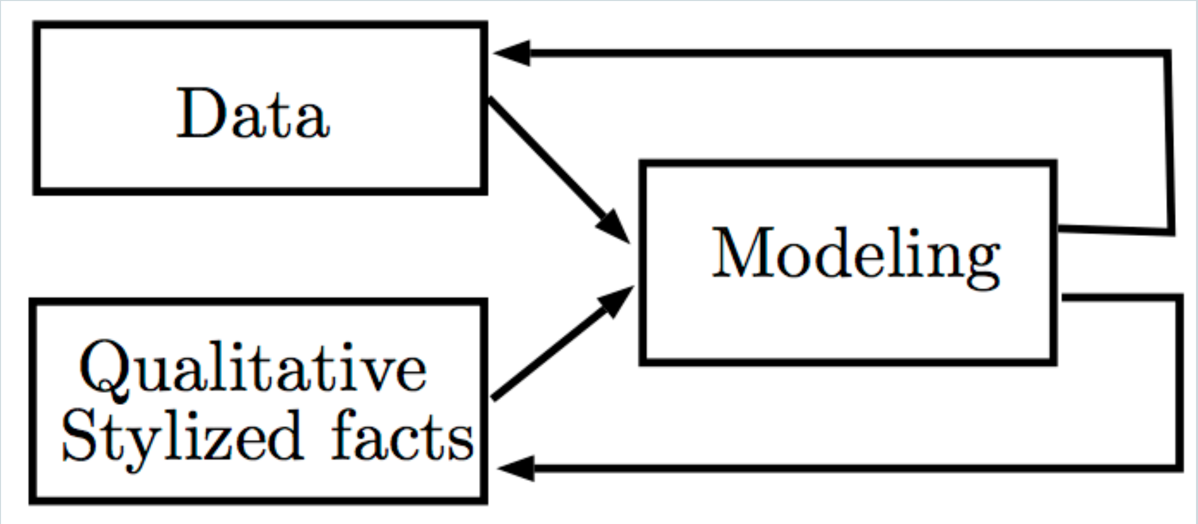
- The model shows that in real situation the regime of job congestion dominates
- The importance of accessibility relative to the cost of life does not influence much dynamics at a macro level
- The importance of the external factor relative to the cost of life and the accessibility has a "U-shaped" influence on the role of time

Hybrid Agent-based Modeling

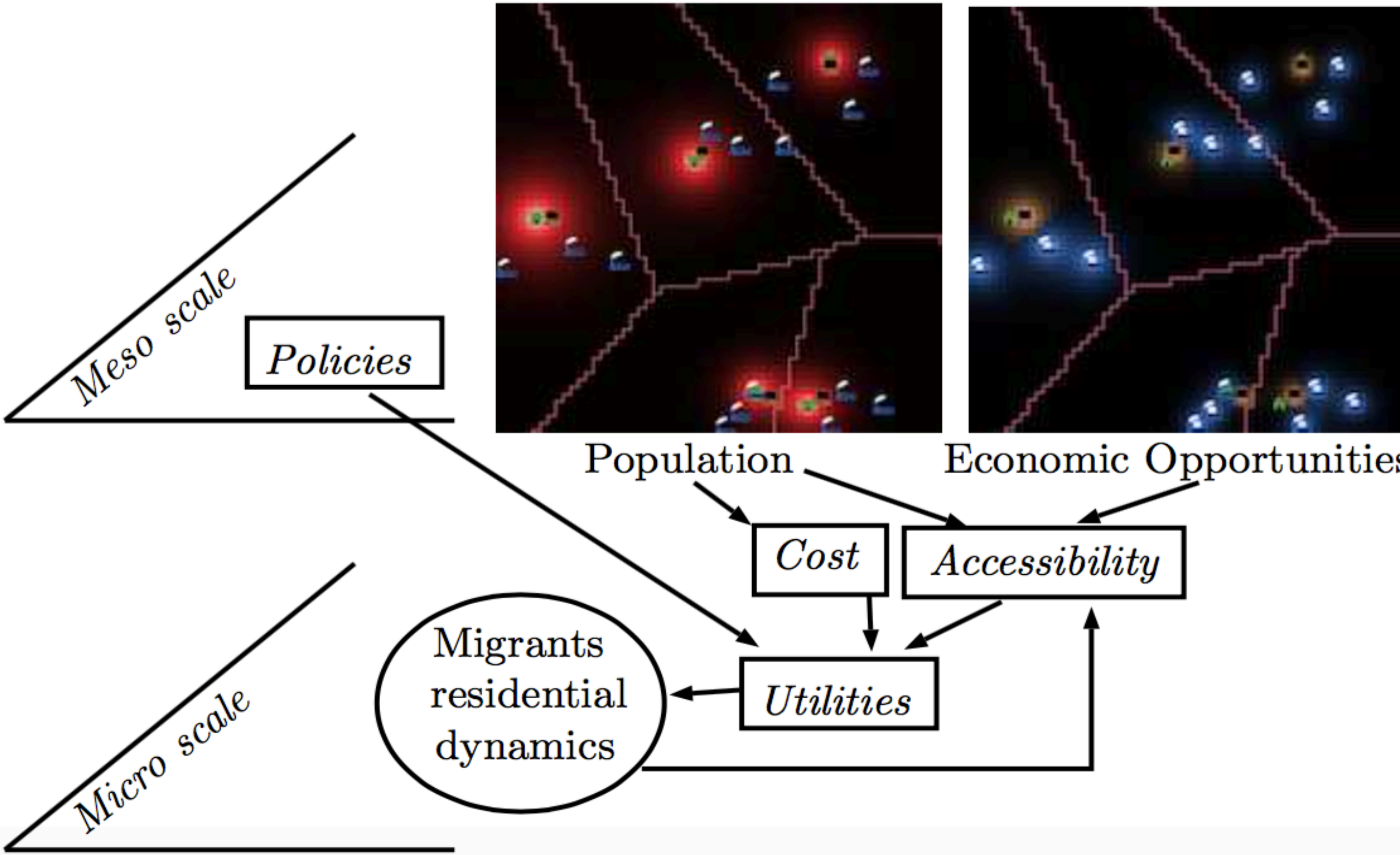
Agent-based Modeling : *from toy to fully parametrized models, to infer indirect knowledge on processes in Complex Systems.*

Recent trends :

- Pattern-oriented Modeling (Grimm et al., 2005)
- Multi-Modeling (Cottineau et al., 2015)
- High Performance Computing calibration (Schmitt et al., 2014).



Model Structure and Ontology



Migration Dynamics

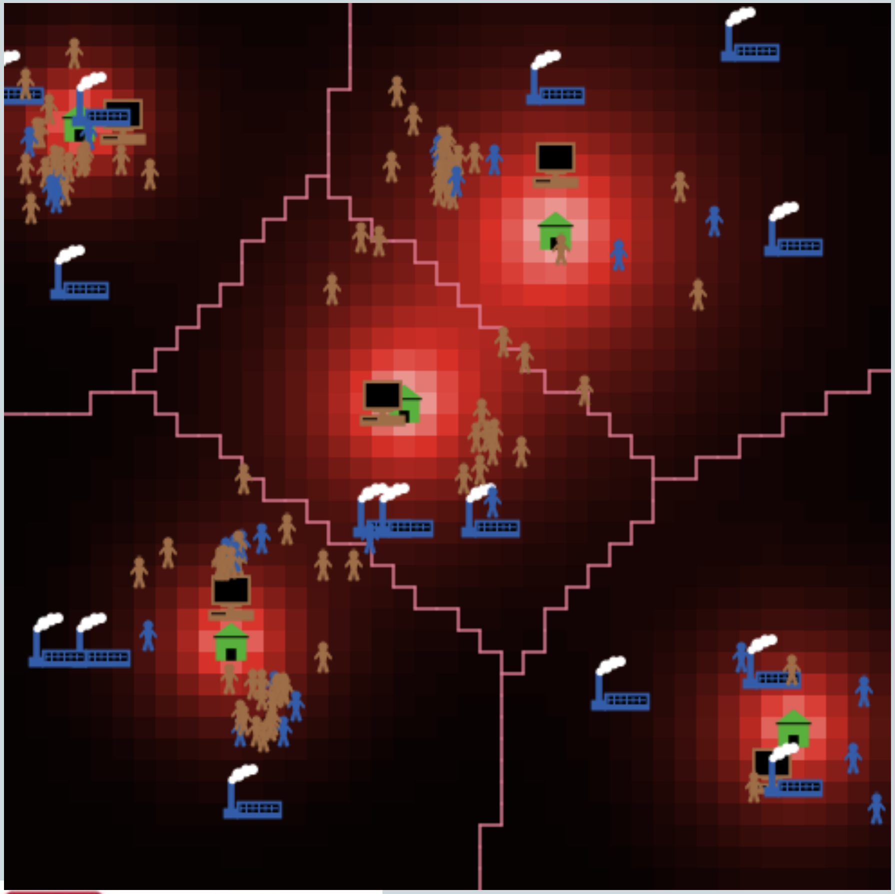
- Variety of economic profiles : migrants wealth $w \sim g(w)$
- Corresponding Economic categories
- Discrete Choice utilities include accessibilities, cost of life and risk aversion, and State regulations with control term $h_j^{(c)}$

$$\Delta U_{i,j}^{(c)}(t) = \frac{Z_j^{(c)} - Z_i^{(c)}}{Z_0} + \gamma \cdot \frac{C_i^{(c)} - C_j^{(c)}}{C_0} - u_i^{(c)} - h_j^{(c)}$$

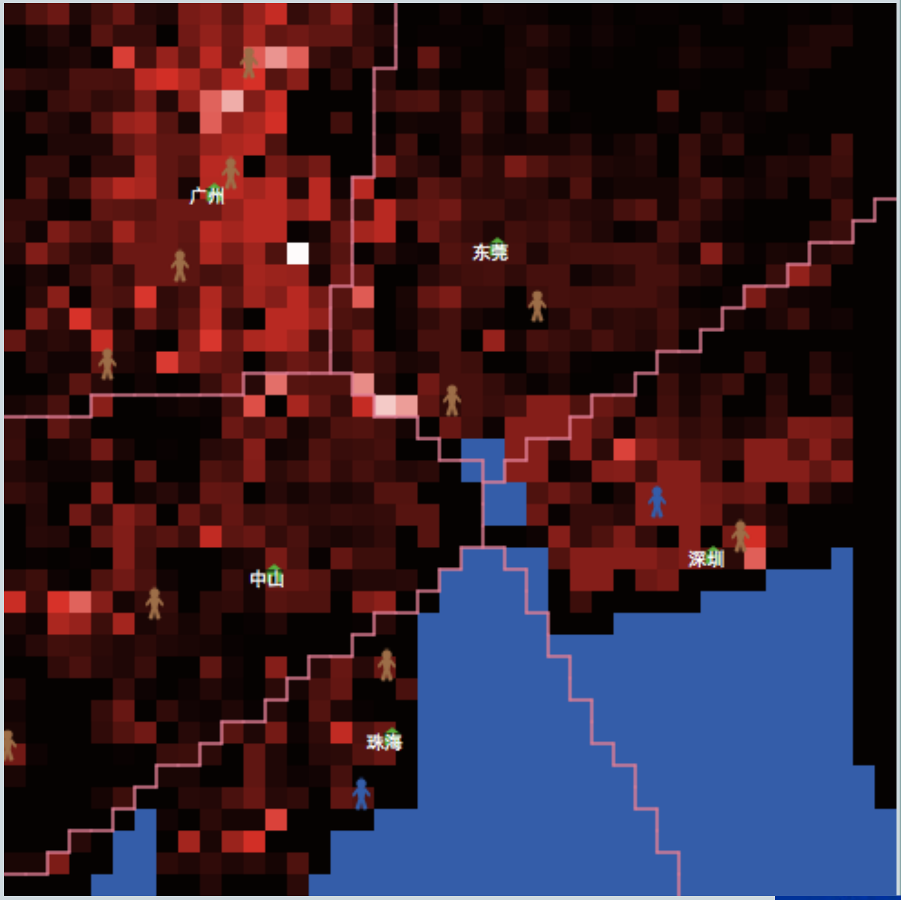
medium
New pathways for sustainable urban development in China's medium-sized cities

Spatial Configurations

Synthetic City System



PRD Stylized Configuration



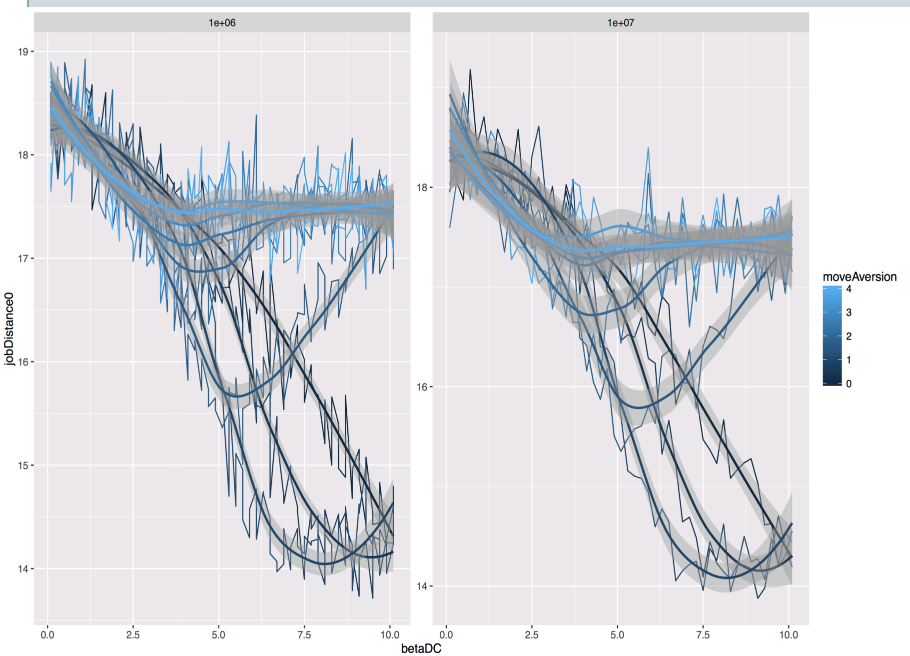
Results : Sensitivity Analysis

Model implemented in NetLogo, explored with OpenMole (Reuillon et al., 2013), around 5 million simulations.

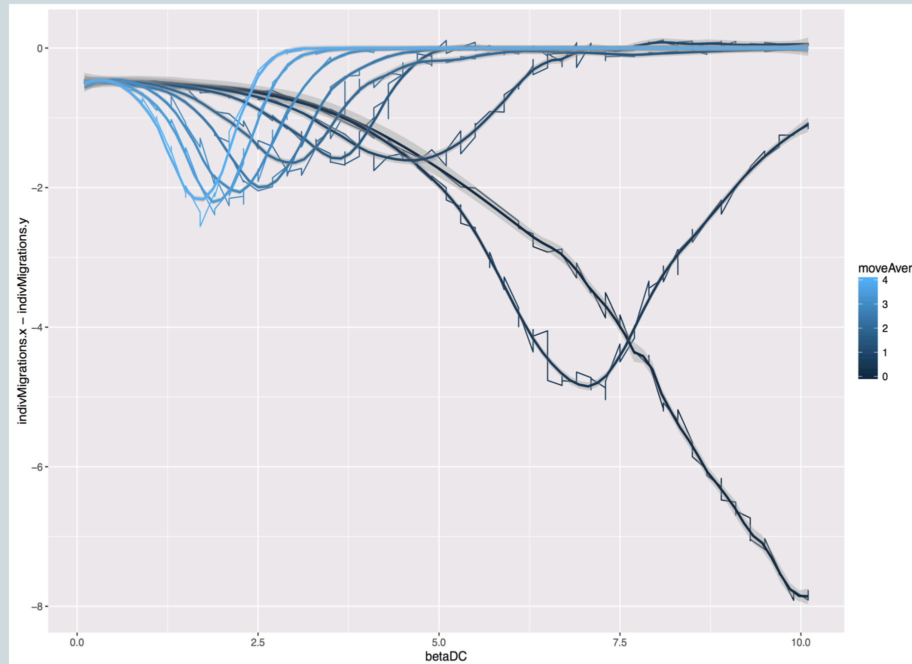
- Sensitivity to economic structure : *Emergent qualitative behavior is not influenced by categories*
- Wealth Distribution Width : *Larger income inequalities yield stronger spatial inequities in job accessibility*
- Income Growth : *Larger enrichments when migrating induces a suboptimal regime for the larger category*

Results : Application

- DPR configuration : *existence of optimal behavior ranges*



- Evaluating Policies: *category-targeted policies control total number of migrations*



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

Perspectives - Conclusion

- External Validation still needs to be further conducted, through more fieldwork, interviews, possibly micro-data
- Further developments : generational dimension ; more diverse socio-economic characteristics
- Potential applications : planning, policy evaluation, processes understanding
- Importance of integrated modeling (qualitative/quantitative) for the approach

All code and data available for reproducibility at https://github.com/JusteRaimbault/MigrationDynamics

Reserve Slides

Reserve Slides

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

Modeling Migration dynamics

Modeling migrations in China :

- (Zhang and Zhao, 2013) estimate discrete choice models to study the trade-off between migration distance and earning difference
- (Fan, 2005) shows that gravity-based models can explain well inter-provincial migratory patterns
- The positive association between wage gap and migration rates was obtained from time-series analysis in (Zhang and Shunfeng, 2003)
- (Wu, 2006) : Empirical study of intra-urban migrants residential dynamics

ABM of migrants dynamics :

- (De Leon et al., 2007) : Border town in Mexico
- (Xie et al., 2007) : agent-based model to simulate the emergence of Urban Villages
- (Silveira et al., 2006) : Ising model of rural-urban migration
- (Fernandez et al., 2005) : study of population characteristics to establish the relevance of a future ABM

Temporal Evolution

At each time step :

- Cities mesoscopic evolution (Gibrat's laws and Scaling laws) ; patch level distribution through preferential attachment scheme
- New migrants enter the city, settle given their social network (关系)
- Discrete choice migrations (randomly drawn for each migrant)
- Update migrants wealths and economic categories
- Update accessibilities

Discrete Choice Utilities

$$\Delta U_{i,j}^{(c)}(t) = \frac{Z_j^{(c)} - Z_i^{(c)}}{Z_0} + \gamma \cdot \frac{C_i^{(c)} - C_j^{(c)}}{C_0} - u_i^{(c)} - h_j^{(c)}$$

where $Z_i^{(c)}$ is generalized accessibility given by $Z_i^{(c)} = P_i \cdot \sum_k \left[E_k^{(c)} - W_k^{(c)} \right] \cdot \exp\left(\frac{-d_{ij}}{d_0}\right)$, with d_{ij} effective travel distance [1] and d_0 commuting characteristic distance ; the parameter γ is the ratio giving the relative importance of life cost compared to accessibility in the migration decisions ; $C_i^{(c)}$ is the cost of life which is a function of cell and city variables, that will be taken as $C_i^{(c)} \propto P_i^{\alpha_0} \cdot \tilde{P}_i^{\alpha_1} \cdot$; $u_i^{(c)}$ a baseline aversion to move and $h_j^{(c)}$ an exogenous variable corresponding to regulation policies ; Z_0 and C_0 dimensioning parameters.

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

Discrete Choice Probabilities

Migration occur following a discrete choice dynamics : the probability to move to cell j is given by

$$\mathbb{P}[i \to j|c] = \frac{\exp\left(\beta \cdot U_j^{(c)}\right)}{\sum_k \exp\left(\beta \cdot U_k^{(c)}\right) + \exp\left(U_{stay,i}^{(c)}\right)}$$

what simplifies into a reduced form, with $\beta' = \frac{\beta}{Z_0}$, $\gamma' = \frac{\gamma}{Z_0 C_0}$ and $\tilde{u}, \tilde{h}$ accordingly rescaled variables, using the above utility expression :

$$\mathbb{P}[i \to j|c] = \frac{\exp\left(\beta' \cdot \left[\Delta Z_{i,j}^{(c)} - \gamma' \cdot \Delta C_{i,j}^{(c)} - \tilde{u}_i^{(c)} - \tilde{h}_j^{(c)}\right]\right)}{1 + \sum_k \exp\left(\beta' \cdot \left[\Delta Z_{i,k}^{(c)} - \gamma' \cdot \Delta C_{i,k}^{(c)} - \tilde{u}_i^{(c)} - \tilde{h}_k^{(c)}\right]\right)}$$

Residential movement is drawn randomly according to these probabilities, and jobs are chosen around new residence following an exponentially decreasing probability.

Policies Scenarisation

"Merit-based" point systems to obtain urban Hukou, implemented differently depending on cities.

-> Translated as N random cities having a fixed incentive for the upper class

($h_j < 0$)

medium

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

Parameters Summary

Parameter	Name	Values	Process
γ	Cost/Accessibility ratio	$\log \gamma \in [5; 8]$	Mobility
u_0	Move aversion	$u_0 \in [0; 5]$	Risk aversion
β	Discrete Choices	$\beta \in]0; +\infty[$	Determinism
g_w	Income Growth	$g_w \in [0; 1]$	Wealth Increase
d_0	Accessibility Decay	$d_0 \in]0; +\infty[$	Accessibility
σ	Wealth dispersion	$\sigma \in [0.1; 1.0]$	Economic Inequalities

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

Indicators

- Total migrants wealth gain
- Total migrants social mobility
- Cumulated utility difference in migrations
- Inequalities are captured by the final ratio between socio-economic categories

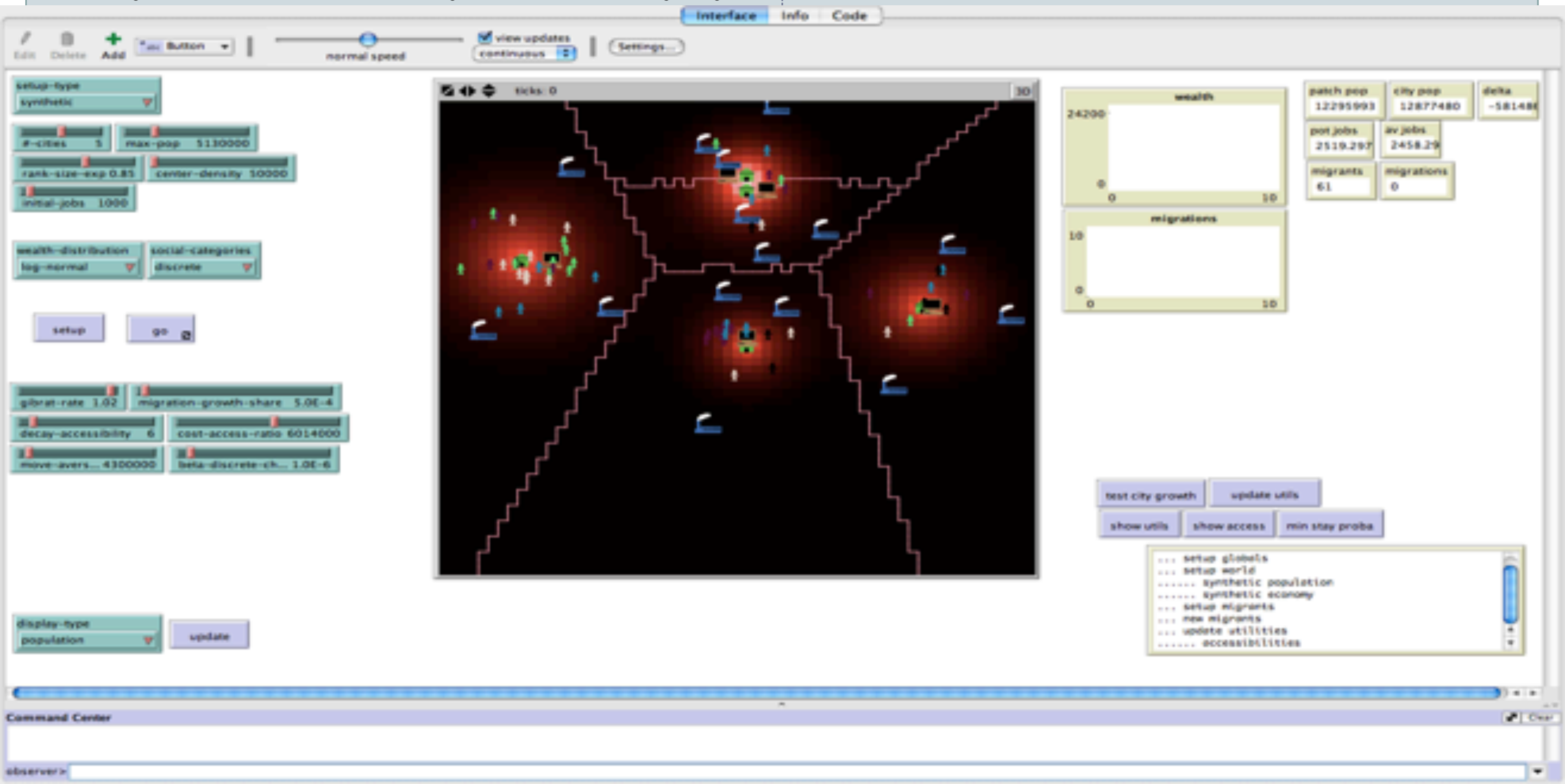
Data sources

- Economic Data : (Swerts, forthcoming), from economic census
- Population Data : Grid Population of China, 1km resolution (Fu, 2010)

Model Implementation

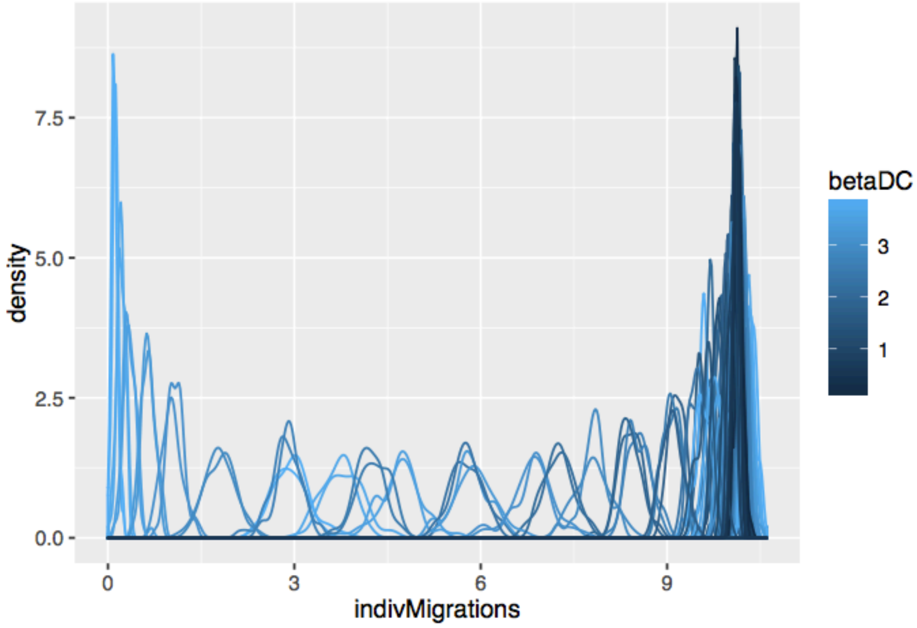
Implementation in NetLogo (Wilenski, 1999) ; High Performance Computing exploration with OpenMole (Reuillon et al., 2013)

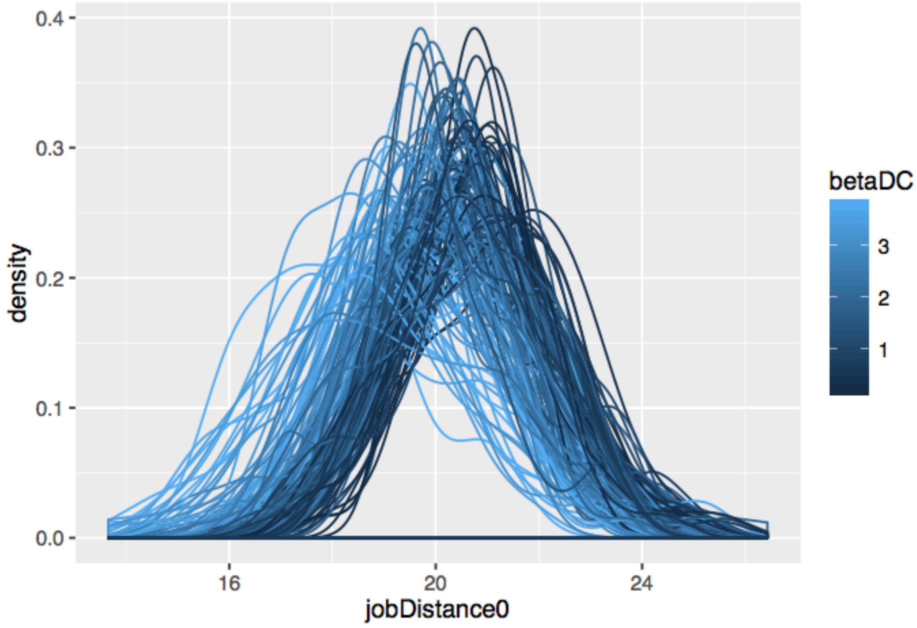
Synthetic Data : Synthetic city system



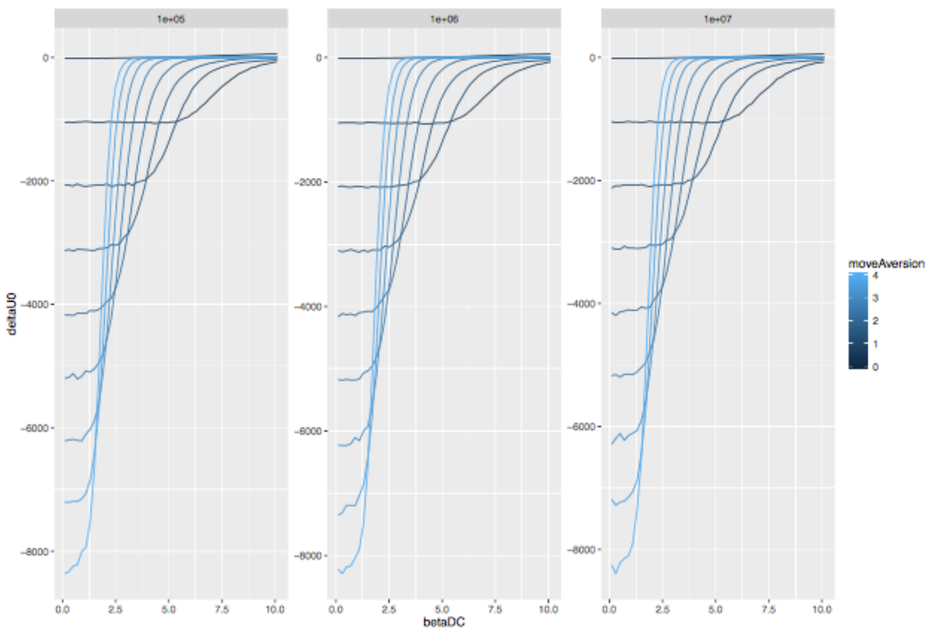
Internal Validation

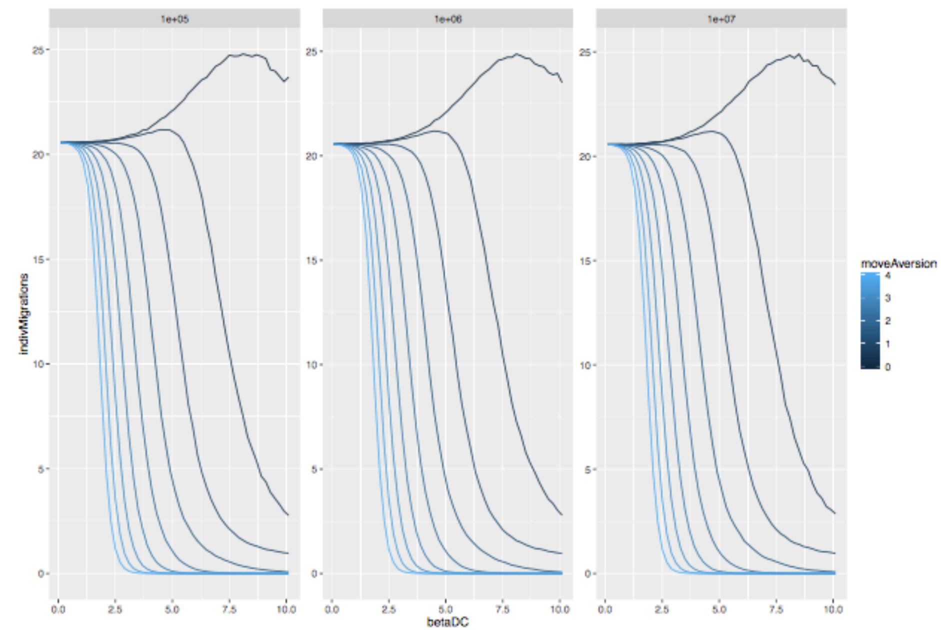
Internal validation by checking statistical convergence and establish number of repetitions needed

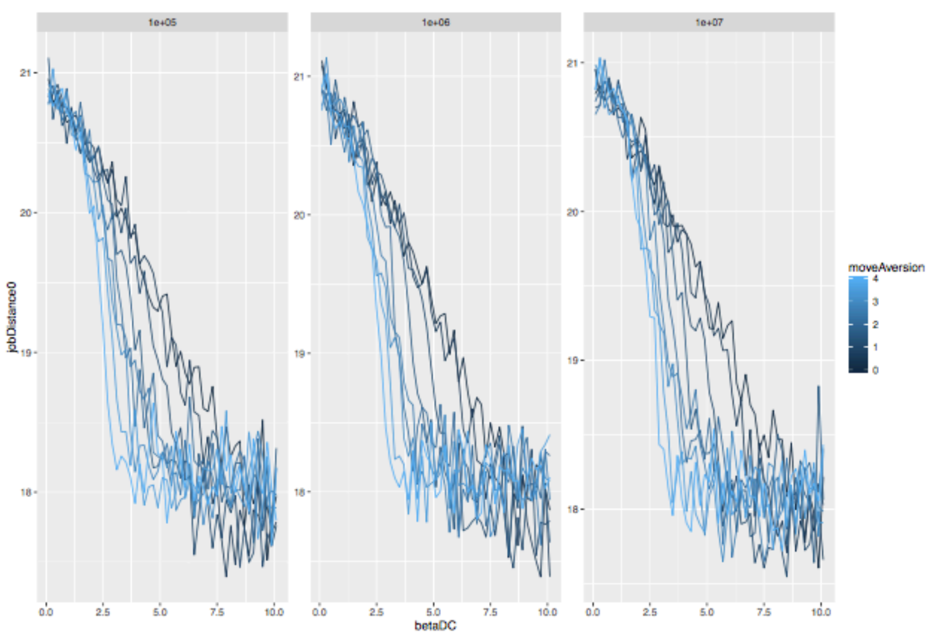


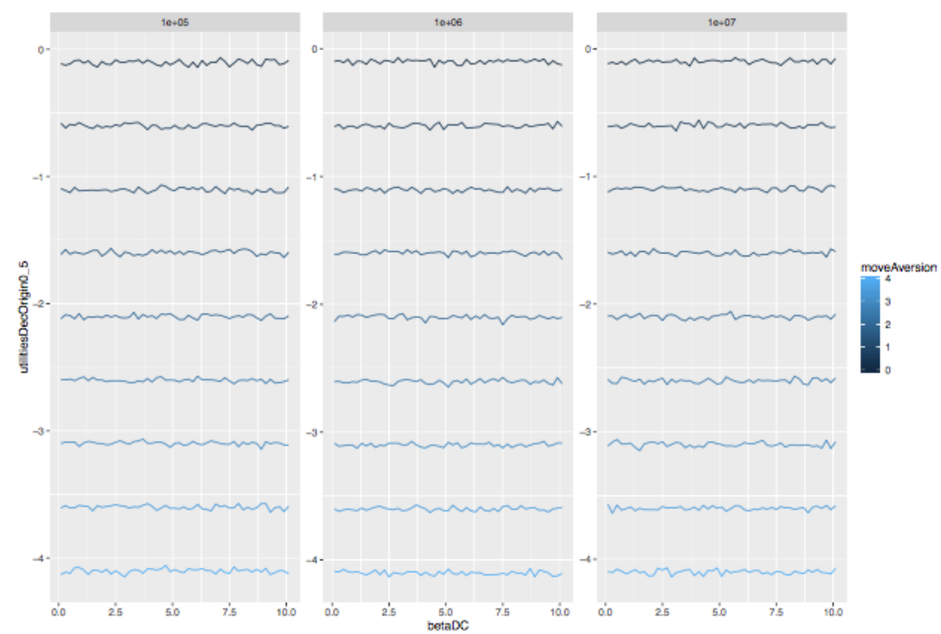


Baseline Behavior

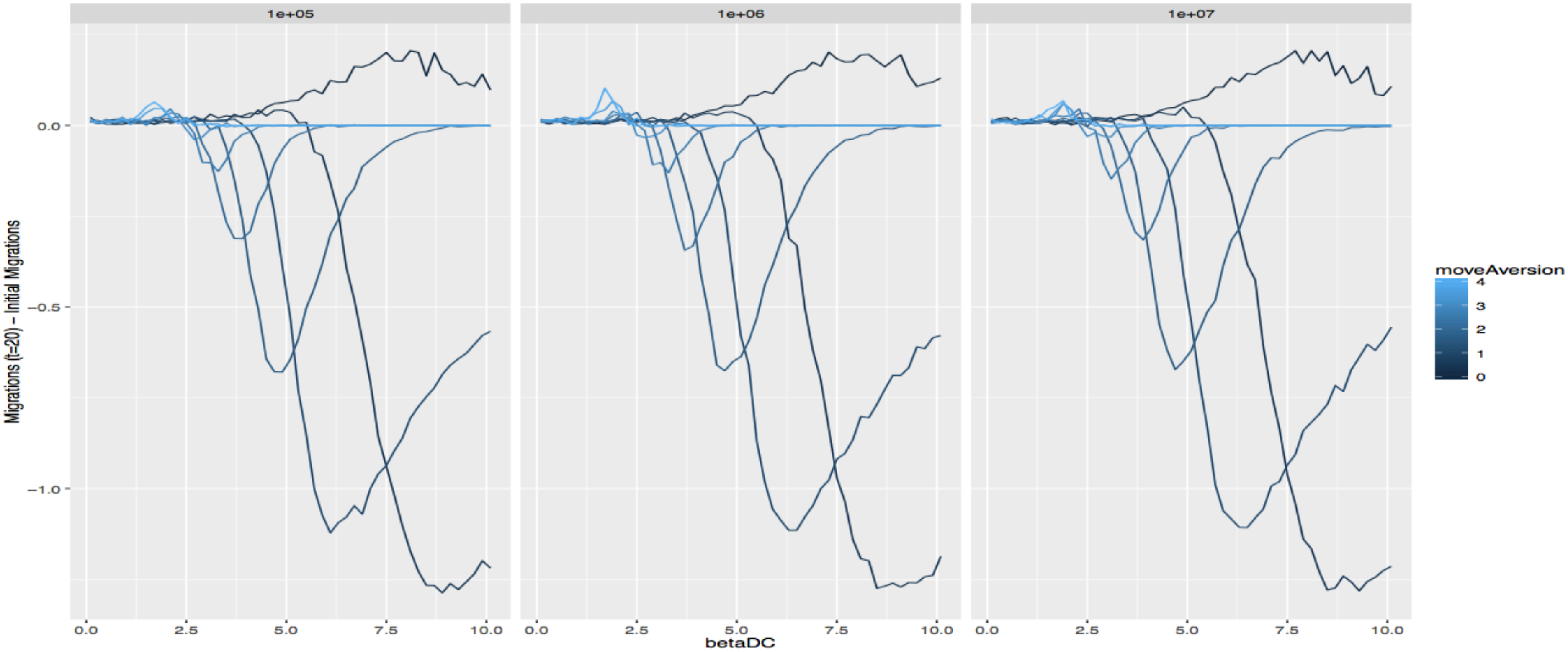




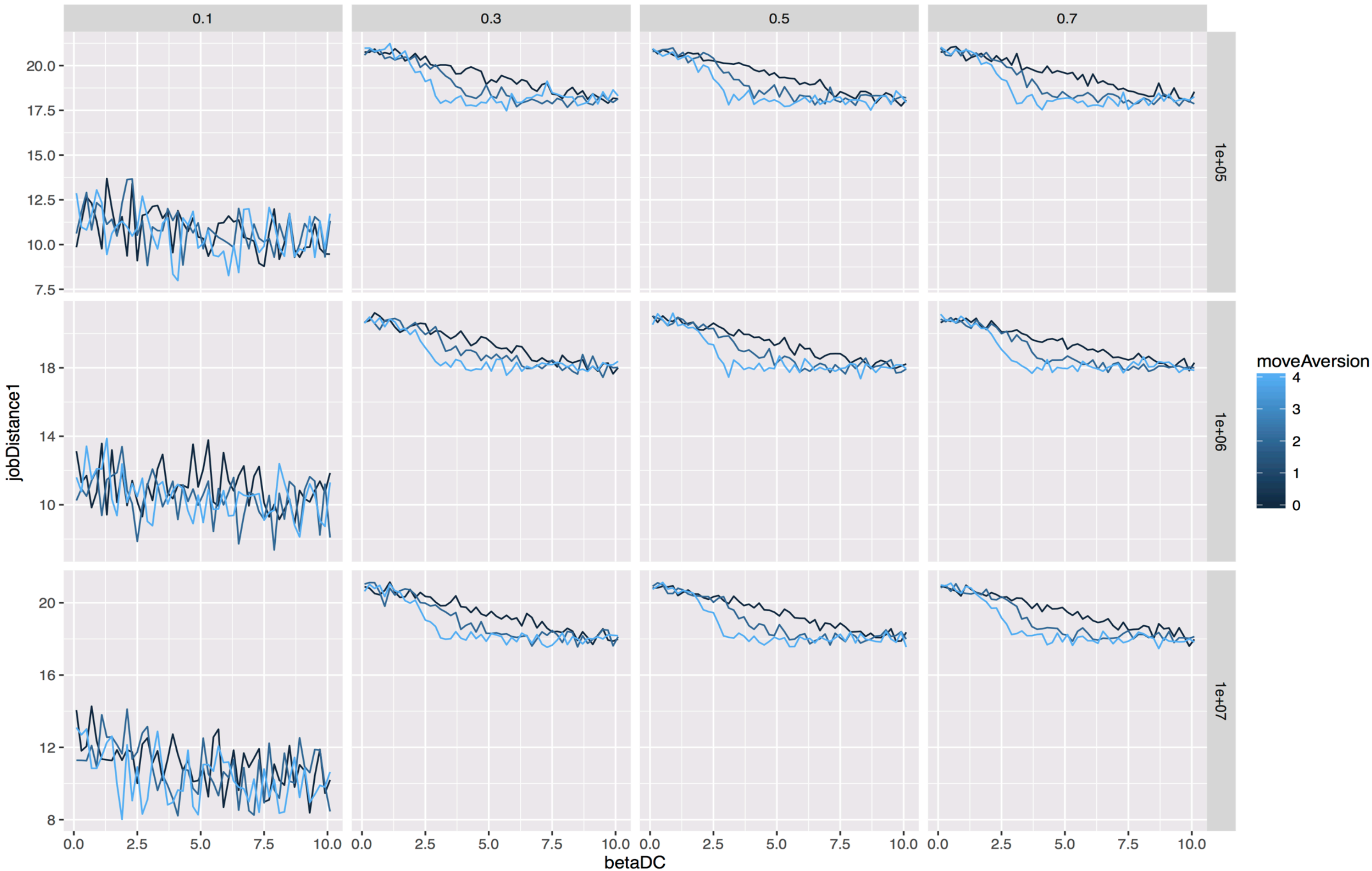




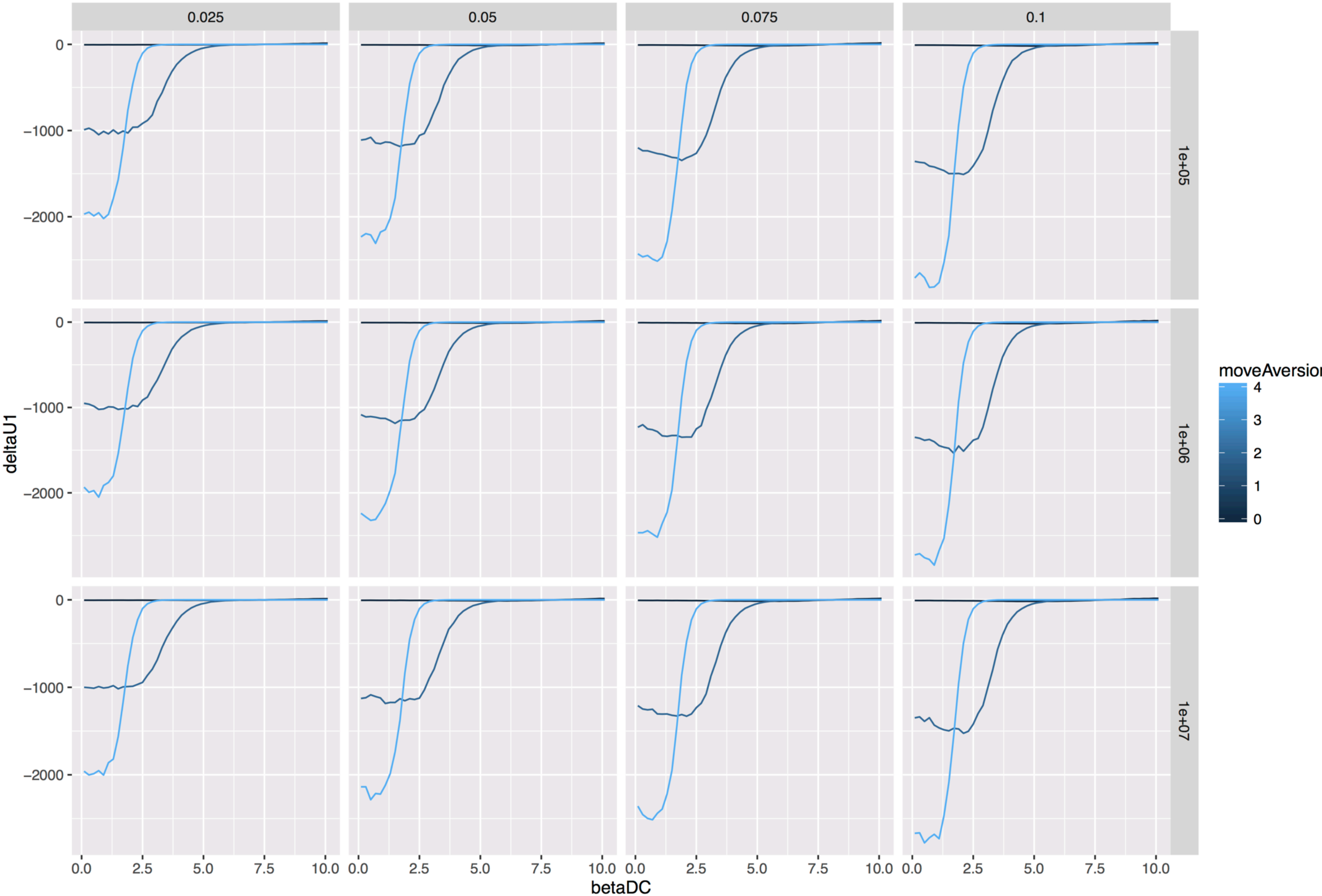
Baseline Behavior



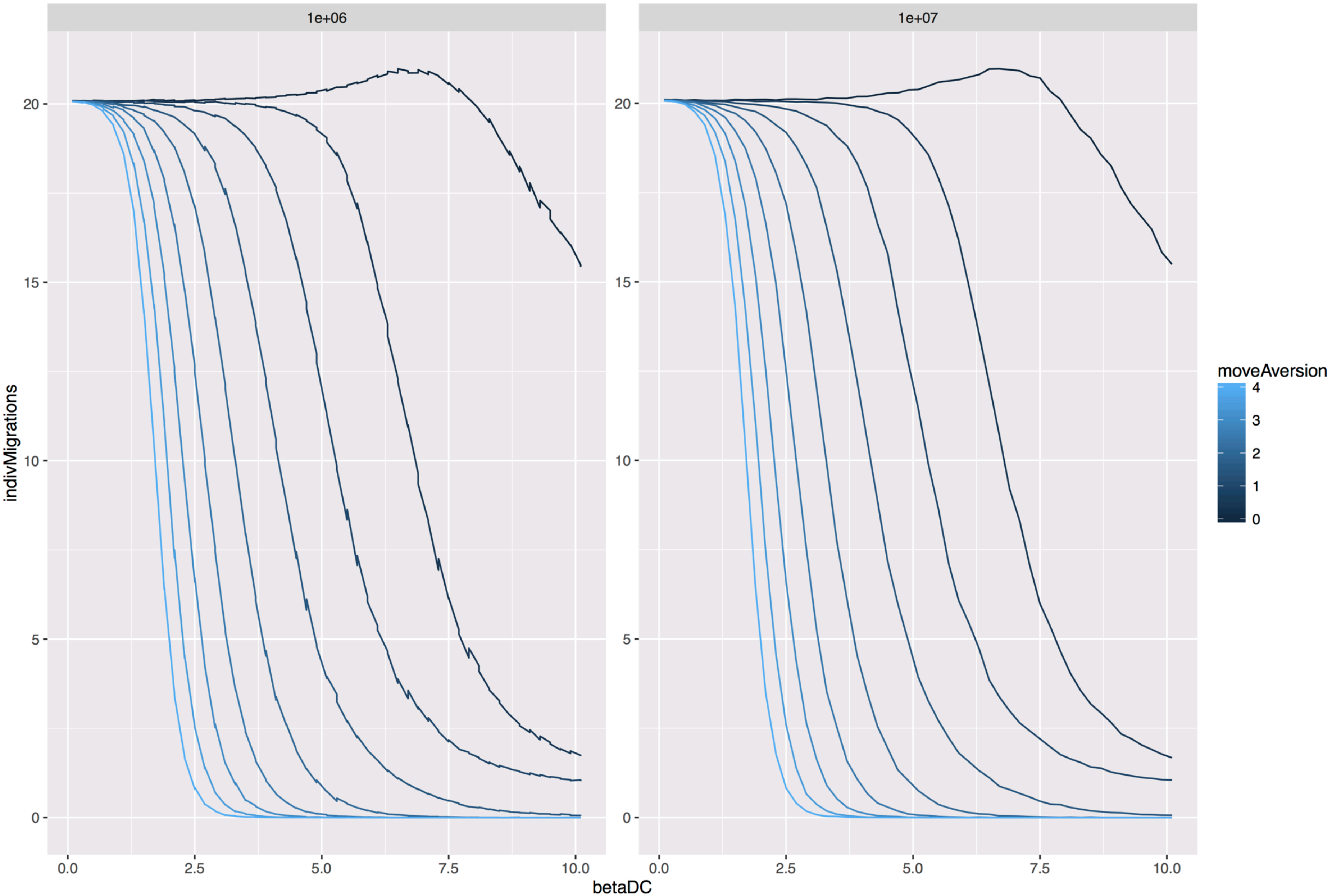
Sensitivity : Distribution Width



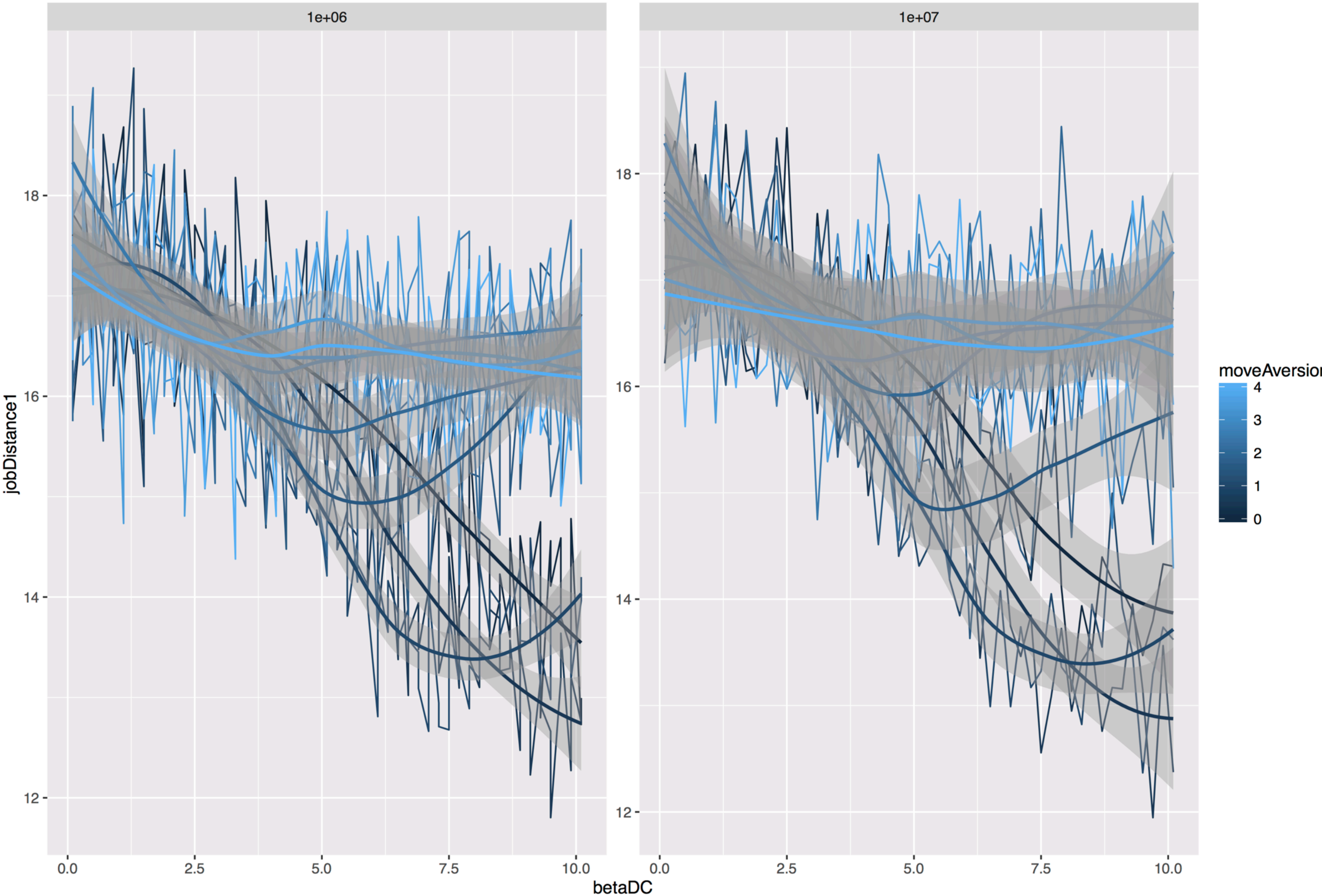
Sensitivity : Distribution Width



Real Configuration



Real Configuration



References

Cottineau, C., Chapron, P., and Reuillon, R. (2015).
An incremental method for building and evaluating agent-based model
of systems of cities.

De Leon, F., Felsen, M., and Wilensky, U. (2007).
Netlogo urban suite-tijuana bordertowns model.
Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Fan, C. C. (2005).
Modeling interprovincial migration in china, 1985-2000.
Eurasian Geography and Economics, 46(3):165–184.

Fernandez, L. E., Brown, D. G., Marans, R. W., and Nassauer, J. I. (2005).
Characterizing location preferences in an exurban population: implications for agent-based modeling.
Environment and Planning B: Planning and Design, 32(6):799–820.

Florida, R., Gulden, T., and Mellander, C. (2008).
The rise of the mega-region.
Cambridge Journal of Regions, Economy and Society, 1(3):459–476.

FU, J., JIANG, D., and HUANG, Y. (1).
km grid population dataset of china (2005, 2010). global change research data publishing and repository, 2014. doi: 10.3974/geodb. 2014.01. 06. v1.

Gottman, J. (1961).
Megalopolis.
Twentieth Century Fund.

Grimm, V., Revilla, E., Berger, U., Jeltsch, F., Mooij, W. M., Railsback, S. F., Thulke, H.-H., Weiner, J., Wiegand, T., and DeAngelis, D. L. (2005).
Pattern-oriented modeling of agent-based complex systems: lessons from ecology.
science, 310(5750):987–991.

Reuillon, R., Leclaire, M., and Rey-Coyrehourcq, S. (2013).
Openmole, a workflow engine specifically tailored for the distributed exploration of simulation models.
Future Generation Computer Systems, 29(8):1981–1990.

Schmitt, C., Rey-Coyrehourcq, S., Reuillon, R., and Pumain, D. (2014).
Half a billion simulations: Evolutionary algorithms and distributed computing for calibrating the simpoplocal geographical model.

Silveira, J. J., Espíndola, A. L., and Penna, T. (2006).
Agent-based model to rural–urban migration analysis.
Physica A: Statistical Mechanics and its Applications, 364:445–456.

Wilensky, U. (1999).
Netlogo.

Xie, Y., Batty, M., and Zhao, K. (2007).
Simulating emergent urban form using agent-based modeling: Desakota in the suzhou-wuxian region in china.
Annals of the Association of American Geographers, 97(3):477–495.

Zhang, J. and Zhao, Z. (2013).
Measuring the income-distance tradeoff for rural-urban migrants in china.

Zhang, K. H. and Shunfeng, S. (2003).
Rural–urban migration and urbanization in china: Evidence from time-series and cross-section analyses.
China Economic Review, 14(4):386–400.