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

Working Paper

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Abstract

Over the last three decades, rural-urban migrant-workers have been a driving force for China's economy, raising attention on associated socio-economical issues. However, the importance of their economic diversity and social mobility has been poorly considered in the analysis of urban development strategy. We use an agent-based model to simulate residential dynamics of migrants in Pearl River Delta (PRD) mega city region, taking into account the full range of migrants' socio-economical status and their evolution. Mega-city regions have become a new scale of Chinese State regulation, and PRD represent the most prosperous and dynamic one in term of migration waves, standing as an ideal unit of analysis. Our model unveils emergent patterns of dynamics, from micro behavior rules of discrete mobility choices. These choices are conditional to urban and economic environment, which evolution is controlled by meso-scale independent dynamics. The two scales are coupled through the dependance of discrete choice utilities to generalized accessibility that combines patch-level urban and economic context with a feedback of the dynamics themselves. We perform simulations to validate the model on synthetic data, by assessing statistical consistence and establishing phase diagrams across the parameter space. The application to the case study allows first to test how variation in socio-economic status yield more complex trajectories, and secondly to identify how the Party-State persist in controlling internal migration flows in a more sophisticated and strategically redefined way.

Keywords : *Mingong ; Residential Dynamics ; Agent-based Modeling ; Zhuijiang Delta Mega-city Region*

1 Introduction

Modeling Rural-urban migrations   [Todaro, 1969] classical equilibrium model

Modeling Rural-urban migrations in China   Existing works in rural-urban migration modeling in China are mainly econometric studies, relying on census or on survey data. [Zhang and Zhao, 2013] estimate discrete choice models to study the tradeoff between migration distance and earning difference. [Fan, 2005] shows that gravity-based models can explain well inter-provincial migratory patterns, implying an underlying strong dominant aggregation processes. The positive association between wage gap and migration rates was obtained from time-series analysis in [Zhang and Shunfeng, 2003].
   Intra-urban residential dynamics : empirical study in [Wu, 2006]

Towards an agent-based modeling approach   To the best of our knowledge, there was no attempt in the literature before to focus on China's migration issues from an agent-based perspective. The case of Mexico was tackled by [De Leon et al., 2007], but in the particular case of a border-town, and underlying processes are furthermore fundamentally different.

[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.

The idea of applying complexity paradigms to rural-urban migration is far from new, as [Mabogunje, 1970] already theorized it in the frame of General System Theory, that for some is viewed as a precursor of complexity theories.

Following a logic of *Pattern-oriented modeling* [Grimm et al., 2005], combined with recent advances in multi-modeling [Cottineau et al., 2016], one can use agent-based models as powerful tools to test qualitative hypothesis, with a reasonable need for empirical data through toy-models or hybrid models.

2   Model

2.1   Rationale

We choose to focus on particular processes and stylized facts to include in the agent-based models, in order to test some hypothesis formulated after qualitative research done in [Losavio, 2016]. More precisely, a recent shift in socio-economic structure of migrating population was observed, including a rise of middle-income migrants and a relativisation of the role of *Hukou* in migration dynamics. The core of the model is thus centered on the exploration of the impact of a varying population economic structure for migrants on system dynamics, and the influence of government migration policies.

Scale   As shown by [Chan, 2012], migration dynamics feature since last three decades a high asymmetry from central regions to coastal economically dynamic province. At a macroscopic scale, explanatory variables are relatively well understood and gravity-based geographical models have a reasonable explanatory power [Fan, 2005]. However, at a regional scale, migration dynamics are also highly present and present more complex patterns. The scale of the model is therefore a regional scale, in the spirit of a *Mega-city Region* [Hall and Pain, 2006], in which urban dynamics are highly complex. A relevant case study to apply the model will be the Pearl River Delta Region in Guangdong.

Ontology   At a mesoscopic scale, i.e. for cities within the MCR, growth can be reasonably assumed independent from migrants movements : they follow larger economic urban processes. Conditionally to such population and economic context, migration dynamics occur at the microscopic scale. We postulate a simple utility-maximization process.

2.2   Model Description

Setup   The world consists in a lattice of $1 \leq i \leq N$ cells, characterized by their population $P_i(t)$ and an economic structure $E_i^{(c)}(t)$ which consists in abstract variables representing potential number of jobs stratified by socio-economic classes c. The associated effective number of workers is denoted by $W_i^{(c)}(t)$. For the sake of simplicity, we assume a discrete number of classes. At initial time, the variables are initialized either following a synthetic data generation process (see below), or from real geographical data (abstracted and simplified to fit our context). Cells are grouped into $1 \leq k \leq K$ administrative cities that corresponding to the various centers of the MCR, on which aggregated population $\tilde{P}_k(t)$ and corresponding economic variables $(\tilde{E}_k^c(t))$ can be computed.

Agents   An agent is a household of migrants, whose residence and job are located in cells (that can be different). Socio-economic structure of the population is captured by the distribution of wealth $g(w)$, which are then stratified into categories. At a given time, the utility difference between not moving and moving to cell j from cell i, for a category c is given by

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

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 (in public transportation ; *point to be clarified : for higher classes, car may be an option*) and d_0 commuting characteristic distance ; $C_i^{(c)}$ 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.

Temporal Evolution   At each time step, the system evolves sequentially according to the following rules :

1. Cities mesoscopic variables $\tilde{P}_k(t)$ and $\tilde{E}_k^c(t)$ are deterministically updated. Population follows the very simple assumption of the expectancy of a Gibrat's law, i.e. $\tilde{P}_k(t) = g_k \cdot \tilde{P}_k(t-1)$. Economy follows a scaling law of population: $\tilde{E}_k^{(c)}(t) = E_k^{(c,0)} \cdot \left(\frac{\tilde{P}_k(t)}{P_0} \right)^{\gamma_k^{(c)}}$.

2. Patches variables are updated conditionally to the new aggregated values. For population, we adapt the aggregation-diffusion process detailed in [Raimbault, 2016]: a density ceil is introduced and diffusion is replaced by spatial noise[1].

3. A number of new migrants, proportional to Gibrat growth rate, enter the region. They lean on social network to first settle in the city and agglomerate following a preferential attachment by place of origin.

4. 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 $\beta' = \frac{\beta}{Z_0}$, $\gamma = \frac{Z_0}{C_0}$ and $\tilde{u}, \tilde{h}$ accordingly rescaled variables, using the above utility expression :

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

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

5. Migrants update their wealth and eventually economic category

Indicators

- Total migrants wealth gain

- Total migrants social mobility

Synthetic Data Generation   *TBW*

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[1]formally, let $\Delta \tilde{P}_k(t) = \tilde{P}_k(t) - \tilde{P}_k(t-1)$

3   Results

Model Validation

- Internal validation : statistical consistence ; system trajectories ; path-dependency.

- External validation : stylized facts from synthetic data exploration ?

Application   *Stylize Pearl River Delta configuration*

Experience Plan   *concrete qualitative questions that can be asked to the model, e.g. :*

- *what is the impact of varying wealth distribution shape and width on system dynamics ?*

- *what is the impact of various spatial distribution of $h_j^{(c)}$, i.e. different government policies ?*

- *Comparison with and without Hong-Kong and Macao*

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References

[Chan, 2012] Chan, K. W. (2012). Migration and development in china: Trends, geography and current issues. *Migration and Development*, 1(2):187–205.

[Cottineau et al., 2016] Cottineau, C., Rey-Coyrehourcq, S., and Reuillon, R. (2016). Back to the future... of multimodelling. In *RGS 2016, Session Geocomputation : the next 20 years*.

[De Leon et al., 2007] 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, 2005] Fan, C. C. (2005). Modeling interprovincial migration in china, 1985-2000. *Eurasian Geography and Economics*, 46(3):165–184.

[Fernandez et al., 2005] 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.

[Grimm et al., 2005] 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.

[Hall and Pain, 2006] Hall, P. G. and Pain, K. (2006). *The polycentric metropolis: learning from mega-city regions in Europe*. Routledge.

[Losavio, 2016] Losavio, C. (2016). Comment analyser l'intégration des ouvriers-migrants dans la chine d'aujourd'hui. le cas de wuhan. *Institut d'études Politiques de Paris. Ecole Doctorale de Science Po.*

[Mabogunje, 1970] Mabogunje, A. L. (1970). Systems approach to a theory of rural-urban migration. *Geographical analysis*, 2(1):1–18.

[Raimbault, 2016] Raimbault, J. (2016). Calibration of a spatialized urban growth model. *Working Paper, draft at https://github.com/JusteRaimbault/CityNetwork/tree/master/Docs/Papers/Density*.

[Silveira et al., 2006] 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.

[Todaro, 1969] Todaro, M. P. (1969). A model of labor migration and urban unemployment in less developed countries. *The American economic review*, 59(1):138–148.

[Wu, 2006] Wu, W. (2006). Migrant intra-urban residential mobility in urban china. *Housing Studies*, 21(5):745–765.

[Xie et al., 2007] 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 and Zhao, 2013] Zhang, J. and Zhao, Z. (2013). Measuring the income-distance tradeoff for rural-urban migrants in china.

[Zhang and Shunfeng, 2003] 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.