Exploring the factors of urban social structure with an agent-based model

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Overall motivation

- numerous work on traffic micro-simulation with agent-based models (ABM)
- questions of "the society": what are the long term effects of congestion, transport pricing / regulation?
- here focus on land use and transport interaction
- existing LUTI models, rather empirical, macroscopic...

  … or microscopic with discrete choice framework
- lack of simulation tools considering explicitly the interactions between economic agents

Main idea

- explore spatial segregation
- literature
  - Brueckner, Thisse and Zénou (1999) "Why is central Paris rich and downtown Detroit poor?…"
  - Goffette-Nagot, Thomas, Zénou (2000)
  - Tivadar and Jayet (2007)
- tool: a cellular automata model coupled with economic agents (households) endowed with behavioural rules (e.g. utility maximisation)
- starting from an explicit theory

Theory

- the model of Urban Economics (Alonso, Mills, Muth model) in Fujita (1989): location choice of households
  - competition for land use
  - transport and time costs to access to jobs and amenities
  - amenities neighbouring effects

Theory (cont'd)

- max! $U(z,s)$
- where *z* a composite good (all consumer goods except land)
- and *s* house size (depends on the distance from CBD)
- budget constraint $Y = z + T(x) + R(x)s(x)$
- transport cost $T(x)$ $\frac{\partial T(x)}{\partial x} > 0$
- rent per unit of land $R(x)$

Theory (cont'd)

- "Bid rent", the maximum rent per unit of land that the household is able to pay for residing at distance *x* from the CBD while enjoying utility *u*

$$\Psi(x,u) = \max_{z,s}\left\{\frac{Y - T(x) - z}{s} \,\middle|\, U(z,s) = u\right\}$$

- and the corresponding "bid-max lot size" $S(x,u)$
- assumption of “normality” of land $\frac{\partial S}{\partial Y} > 0$
- From above, important properties:
  - Bid rent is decreasing in both *x* and *u*
  - Bid-max lot size is increasing in *x* and *u*

Assumptions of the agent-based model

- monocentric city (CBD).
- the space is a discrete grid and each cell is for agricultural use or occupied by a household.
- the cells may accommodate several residential lots from varying size
- households consist in single workers

Assumptions of the agent-based model (cont'd)

- landlords are absent and allocate land to the highest bidder
- rents are negotiated at each time step across the whole area. Households are able to migrate or move within the city at no costs. Because of this competition rents adjust immediately
- the city is open and grows from an initially zero population around its CBD

Assumptions of the agent-based model (cont'd)

- At each time step a given number of immigrants arrive. Each immigrant chooses the location which maximises his utility.
- A short-run equilibrium occurs where the utility is the same for all households of the same kind.
- This succession of short-run equilibria stops when the utility in the city is the same as in the rest of the world: this is the long run equilibrium.

Application

$$U(z,s) = \alpha \log(z) + \beta \log(s(x))$$

- α and $\beta > 0$ and $\alpha + \beta = 1$

$$\Psi(x,u) = \alpha^{\alpha/\beta} \beta (Y - T(x))^{1/\beta} e^{-u/\beta}$$

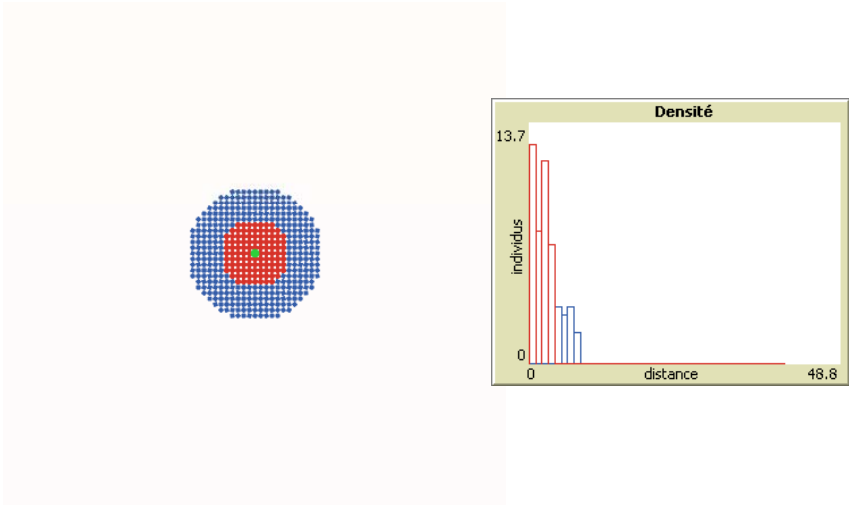
$$S(x,u) = \beta(Y - T(x)) / \Psi(x,u) = \alpha^{-\alpha/\beta} (Y - T(x))^{-\alpha/\beta} e^{u/\beta}$$

$$T(x) = tx$$

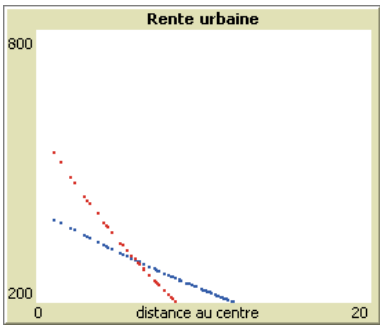
Model 1: heterogeneous individuals

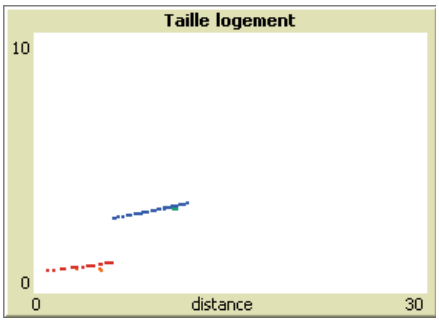
- Two classes of individuals:
  - the "rich" with the same income Y_1
  - the "poor" with the same income Y_2
  - they all need to go to the CBD and they compete for housing in the city

Model 1: heterogeneous individuals



Model 1: heterogeneous individuals



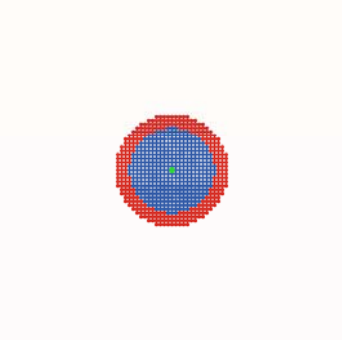


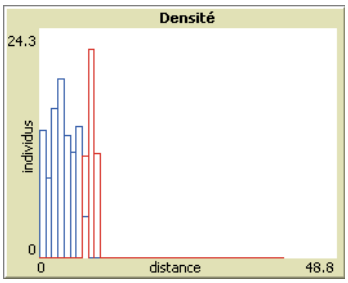
Model 2: introducing transport time costs

$$T(x) = (t + vdt)x$$

- same transport speed for everybody
- however the rich have a higher value of time than the poor

Model 2: introducing transport time costs





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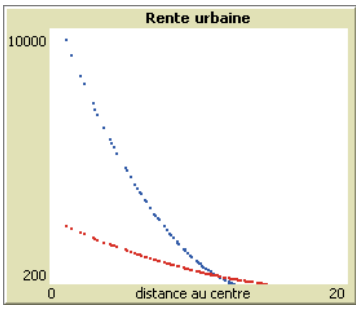
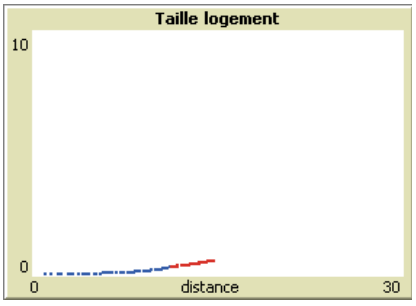




Model 3: introducing amenities

$$U(z,s) = \alpha \log(z) + \beta \log(s(x)) + \gamma \log(a(x))$$

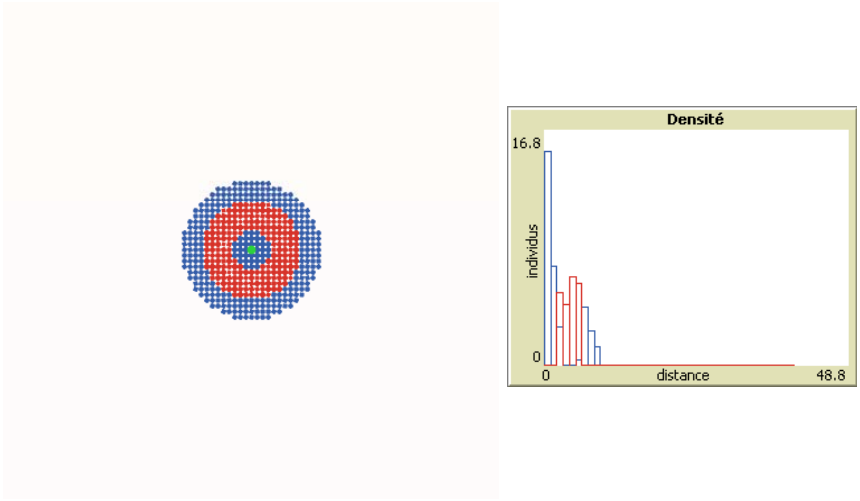
- $a(x)$ an amenity for which households have different preferences $a(x) = a_0 x^{\delta} \qquad \delta < 0$
- $\alpha + \beta = 1$ and $\gamma > 0$

$$\Psi(x,u) = \alpha^{\alpha/\beta} \beta (Y - T(x))^{1/\beta} e^{-u/\beta} a(x)^{\gamma/\beta}$$

$$S(x,u) = \beta(Y - T(x)) / \Psi(x,u) = \alpha^{-\alpha/\beta} (Y - T(x))^{-\alpha/\beta} e^{u/\beta} a(x)^{\gamma/\beta}$$

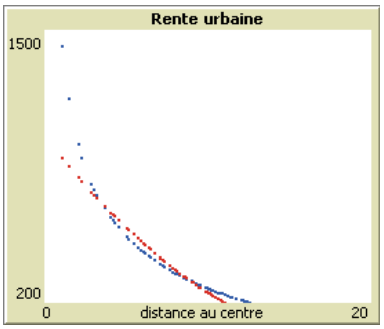
- the rich $\gamma = \gamma_1$ the poor $\gamma = 0$

Model 3: introducing amenities (centre)



Model 3: introducing amenities (centre)

$$\Psi(x,u) = \alpha^{\alpha/\beta}\beta\left(Y - T(x)\right)^{1/\beta} e^{-u/\beta} a(x)^{\gamma/\beta}$$



$$a(x) = a_0 x^{\delta} \qquad \delta < 0$$

Conclusions and perspectives

- rather elementary mechanisms, sufficient to “explain” the emergence of some "stylised facts"
- ongoing work, models still to be fully explored
- perspectives ABM:
  - ILOT: Interaction LOcations Transport (Raux, Jensen, Lemoy et alii)
  - SMA-LOCMOB: Traffic simulation MATSIM (Marchal et alii)
  - MADYNIMMOB: Housing market, landlords and tenants) (Jensen, Goffette-Nagot, Mc Breen et alii)

- Thank you for your attention...

… Any question?