Agent-Based Land Markets: changes in response to increased risk of coastal erosion

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Outline

- Motivation
- Agent-based land market (ALMA)
  - Conceptual scheme
  - Applications
- Case-study:
  - Coastal towns in the Netherlands
- Specific research questions
- Simulation results
- Conclusions

Summary from the previous talk

- Ecological and economics models need to be *integrated*
- They need to be *spatially explicit* and *dynamic*
- They need to integrate *economic behavior* explicitly
- *Land markets* need to be modeled since location, pattern and timing are determined simultaneously

=> a need for a *spatially explicit land market model* structure that facilitates the integration of economic models with the process-based ecological ones

Land use models: economic tools

- Spatial economics:
  - Representative agent
  - Aspati
  - Homog
  - Direct modeling of a land
  - en
  - acro
- Spatial econometrics:
  - Representative agent
  - No direct modeling of a land market
  - Spatially explicit
  - Heterogeneous landscape

Direct modelling of land market interactions among economic agents in a cellular grid?

Why do we need ABM to model LM

- *Heterogeneous agents* vs. homogeneous (Kirman[1]):
  - preferences for location and individual budget differ among different economic agents, such as firms or households, and within these groups
- *Interactions:*
  - Among individual agents
  - Spatial neighborhood
  - Between individuals and local government
- *Heterogeneous* attributes of the *spatial environment*
- *Out-of equilibrium*[2] dynamics

1 - Kirman, A.P., Whom or what does the representative individual represent? Journal of Economic Perspectives, 1992. 6(2): p. 117-136.

2 - Arthur, B., Out-Of-Equilibrium Economics and Agent-Based Modeling, in Handbook of Computational Economics Volume 2: Agent-Based Computational Economics K.L. Judd and L. Tesfatsion, Editors. 2006, Elsevier B.V. p. 1551-1564.

Urban economics

- Alonso[1]: trade-off between travel costs and rent

$$\max_{r,z,s} U(z,s), \quad \text{s.t.} \quad z + s \cdot R(r) = Y - T(r)$$

$$\Psi(r,u) = \max_{z,s} \left\{ \frac{(Y - T(r) - z)}{s} \quad \text{s.t} \quad \mathrm{U(z,s)} = \mathrm{u} \right\}$$

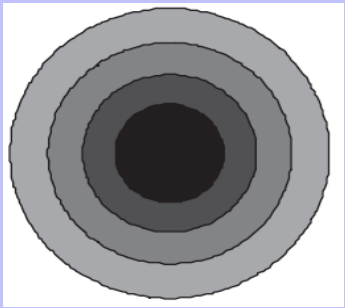


Figure from Wu, Plantinga (2003)[2]

1 - Alonso, W., 1964. Location and Land Use. Cambridge, MA: Harvard University Press.

2 - Wu, J.J. and A.J. Plantinga, The influence of public open space on urban spatial structure. Journal of Environmental Economics and Management, 2003. 46(2): p. 288-309.

Urban economics

- Environmental amenities in the city

$$\max_{r,z,s,a} U(z,s,a) = s^{\alpha} z^{1-\alpha} a(x_1,x_2)^{\gamma},$$

$$\text{s.t.} \quad z + s \cdot R(x_1,x_2) = Y - T(r)$$

$$\Psi(r,u) = \max_{z,s} \left\{ \frac{(Y - T(r) - z)}{s} \right\}$$

$$\text{s.t} \quad U(z,s,a) = u \Big\}$$

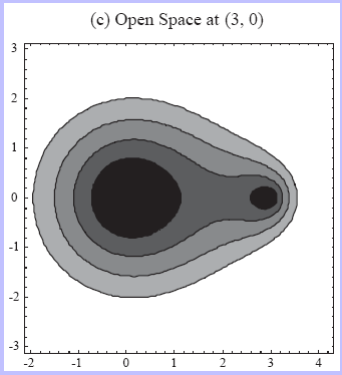


Figure from Wu, Plantinga (2003)[1]

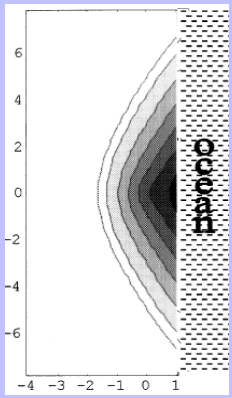


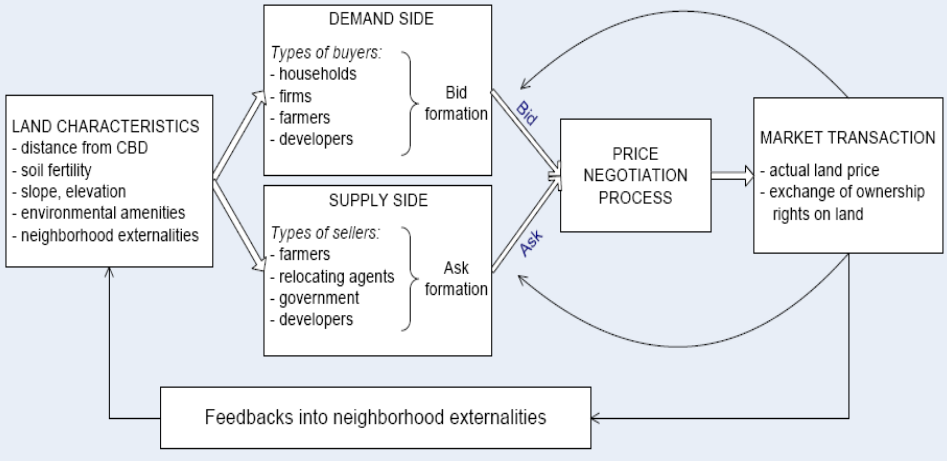
Figure from Wu (2001)[2]

1 - Wu, J.J. and A.J. Plantinga, The influence of public open space on urban spatial structure. Journal of Environmental Economics and Management, 2003. 46(2): p. 288-309.

2 - Wu, J., 2001. Environmental Amenities and the Spatial Pattern of Urban Sprawl. American Journal of Agricultural Economics 83 (3), 691-97.

ALMA – Agent-based Land MArket

- Conceptual scheme



- Centralized price determination is replaced by a set of bilateral trades

ALMA

- Tradable good: spatial good (land lot / house)
- Landscape:
  - A grid of equal cells
  - CBD in the center of Cartesian coordinate system
  - Cells are different in the proximity to the CBD, $P = D_{\max} + 1 - D$
  - Environmental amenities: coast or parks spread randomly
  - Environmental disamenity: probability of flooding or erosion
  - Each cell could be owned by one economic agent
- Agents:
  - Buyers – households
  - Sellers – farmers (or developers)
  - Traded

ALMA: Buyer's behavior

- Utility $U = \alpha \cdot \ln(A) + \beta \cdot \ln(Prox)$
- Expected utility $E(U) = PF_i \cdot U \cdot (1 - C_{dam}) + (1 - PF_i) \cdot U$
- Disposable budget for housing $Y = tc * D + R$
- Bid price $R = \frac{Y * E(U)^2}{b^2 + E(U)^2}$
  - Increasing with u; asymptotic to Y; b scales convexity of U
  - Replicates qualitative properties of an economic demand function
- Boundedly-rational
  - Not perfectly informed (not a global maximum)
  - Myopic (not intertemporal; no optimal timing)
- Heterogeneous
  - Preferences for green amenities
  - Individual coastal risk perception
  - Income

ALMA: Seller's behavior

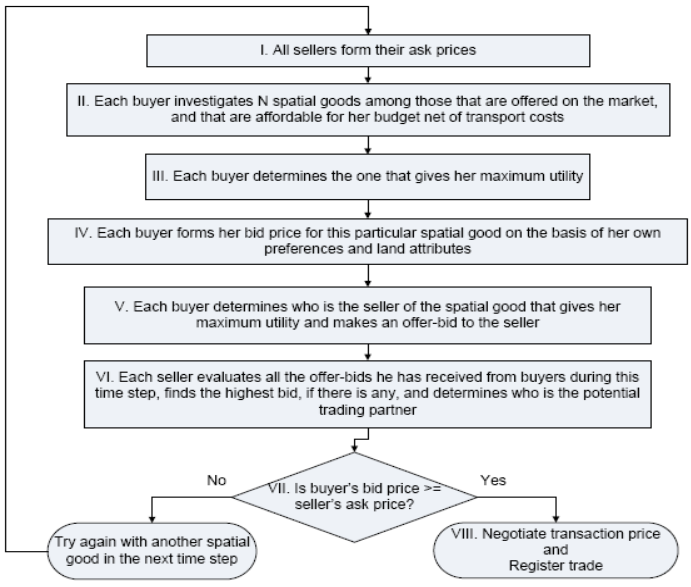
- Opportunity costs: agricultural land price
- Expected buyer's price
- Ask price

- Land price – negotiated in market interactions
  - Arithmetic average
  - Adjusted on the relative market power of economic agents

ALMA

Mechanisms of Trade

Logic of traders' decision making



Related work with ALMA

- Monocentric urban model:
  - With homogeneous individual preferences
    - for CBD / Amenities / Public good
  - With heterogeneous ones
  - Changes in the transportation costs, income
  - Changes in pricing behavior (ask prices depend on neighborhood transactions; traders behavior at buyers' and sellers' markets)
  - Changes in the neighborhood causes dissatisfaction
- Local government
  - Taxes and provision of public good
- Coastal city
  - Coastal view as an amenity: for both homogenous and heterogeneous preferences
  - Introduction of a property tax for the areas close to the coastline
  - Market mechanisms for the preservation of coastal ecosystem services

Case-study: Dutch coastal towns

- Coastal zone in the Netherlands:
  - 70% of Dutch Gross National Product is generated there
  - Ecosystem functions as erosion control, and sediment retention
  - Coastal squeeze: competition for space

    the situation observed in the coastal margin, which is squeezed between fixed landward boundary and the pressure from the sea shrinking the areas available for natural coastal processes to take place
- Climate change
  - more extreme events (severe storms or hurricanes)
  - gradual rise of the sea level
  - => increased probability of flooding or erosion in the coastal area

Coastal towns under risk

- Erosion line
  - Shift due to climate change
- Old urban developments:
  - Outside the dikes areas
- Growing human pressure?
  - Poelmann commission: individual responsibility

Rijkswaterstaat. Hoofdrichtingen voor risicobeheersing in kustplaatsen. Den Haag (2005).

Problem for coastal cities

For the outside the dikes area:
Total economic damage

€ 63 ml

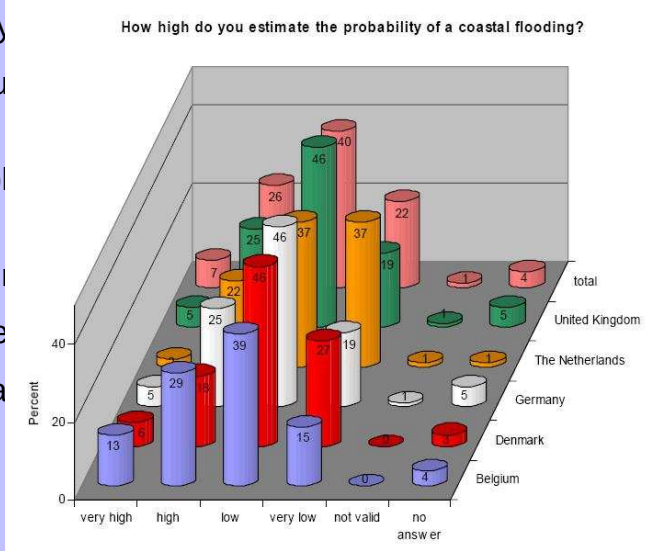
Built-up area - 39%
Business – 38%

- New developments?
- Expanding a hotel ?
- Renewing a house?

Rijkswaterstaat. Hoofdrichtingen voor risicobeheersing in kustplaatsen. Den Haag (2005).

Decisions on different scales

- Policy
within u
- Peopl
- Low i
inefficie
areas a



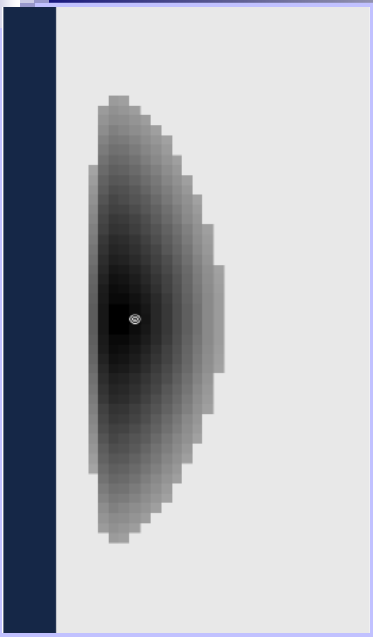
Research questions

- *RQ*:
  - How coastal land markets react (in terms of changed land prices, city size, and amount of urban developments under risk) to an increasing probability of flooding or erosion?
  - How variations in individual perceptions of erosion probability affect aggregated patterns of development and coastal squeeze?
- A tool to:
  - Explore the qualitative trends
  - Quantify and visualize effects

Experiments

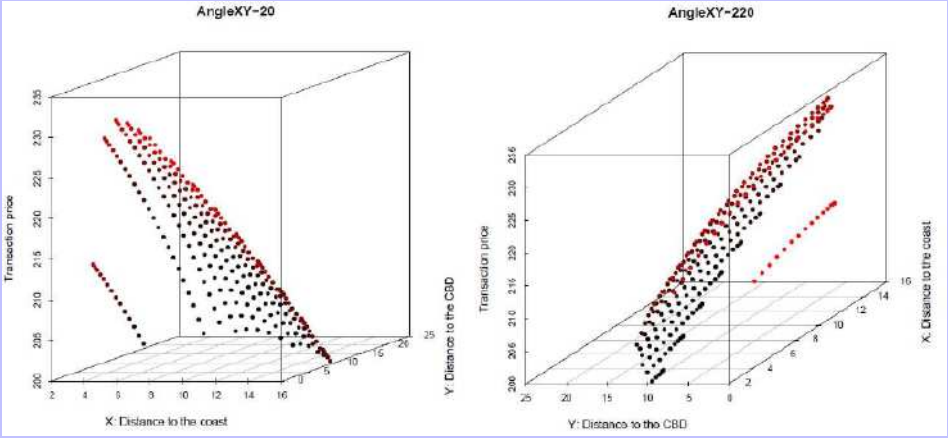
- Settings
  - Constant for the 3 experiments
    - Landscape: 35x63
    - 3780 traders in the land market
    - Price of agricultural land R_{ag}=200
    - Homogeneous preferences for amenities
  - Changed among experiments
    - Position of the erosion line
    - Perception of the risk of coastal erosion
- Macro metrics
  - Welfare measures
  - Economic indicators (land price)
  - Spatial measures (city size, distance at which city border stops)
  - Screenshots of land rent gradients
  - Estimated land rent gradients

Experiment 1: benchmark case



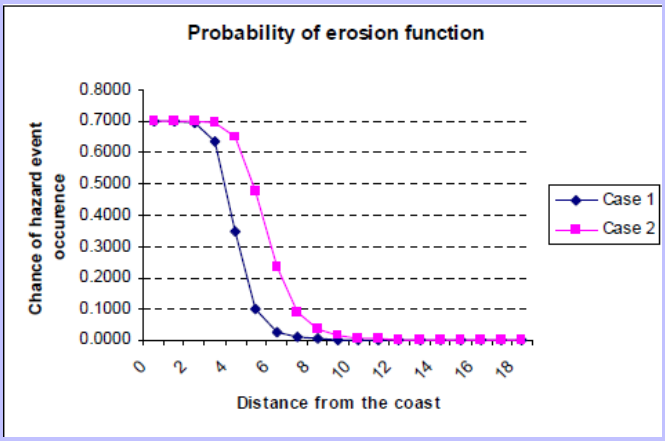
- Settings:
  - Landscape: coastal amenities and disamenities are present
  - Agents: homogeneous preferences for location
- Things to see:
  - Equal rents at equal distances
  - Rent gradient goes down with the distance from the CBD

Experiment 1: 3D rent gradient



Experiment 2: shift of erosion line

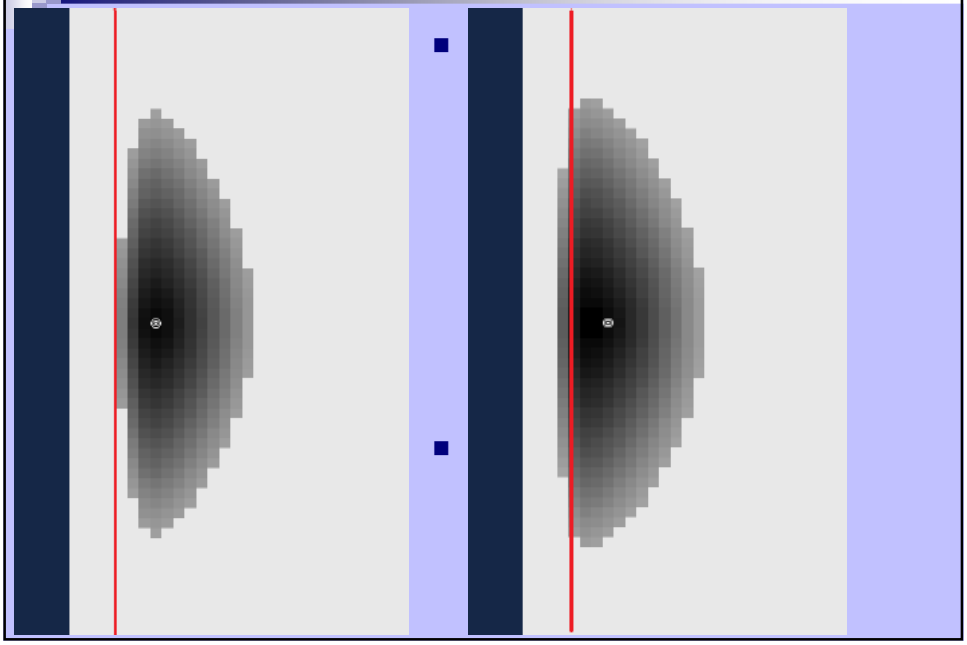
- objective probability of erosion (PF_{obj}) is distance-dependent



Exp1: C_{PF2}=4

Exp2: C_{PF2}=5.5

Experiment 2: shift of erosion line

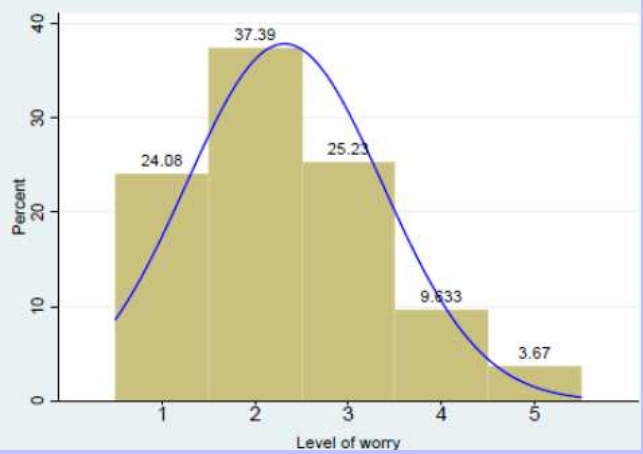


Experiment 1&2

Parameter		*Exp 1*	*Exp 2*	*Exp 3*
Individual utility:	Mean	42.53	42.25	42.32
	St. dev.	0.99	0.88	0.97
Aggregate utility		18754.48	15634.32	17426.57
Buyers' bid price:	Mean	212.93	211.11	211.45
	St. dev.	8.17	7.3	8.03
Sellers' ask price:	Mean	212.93	211.11	209.75
	St. dev.	8.17	7.3	7.77
Urban transaction price:	Mean	212.93	211.11	210.6
	St. dev.	8.17	7.3	7.87
Total property value		93902.49	78110.13	86725.16
City size (urban population)		441	370	411.8
Distance from CBD at which city border stops		22.09	21	22
Urban cells seawards from the safety contour		31	0	4.3

- Increased probability of erosion moves urban developments away from the coast

Experiment 3: *heterogeneous risk perceptions*

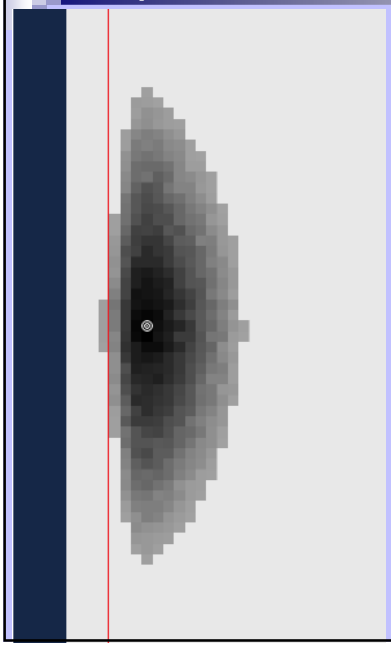


- subjective probability of erosion (PF_i)

$$PF_i = PF_{obj} \pm RP_{dev}, \quad PF_i \in [0;1]$$

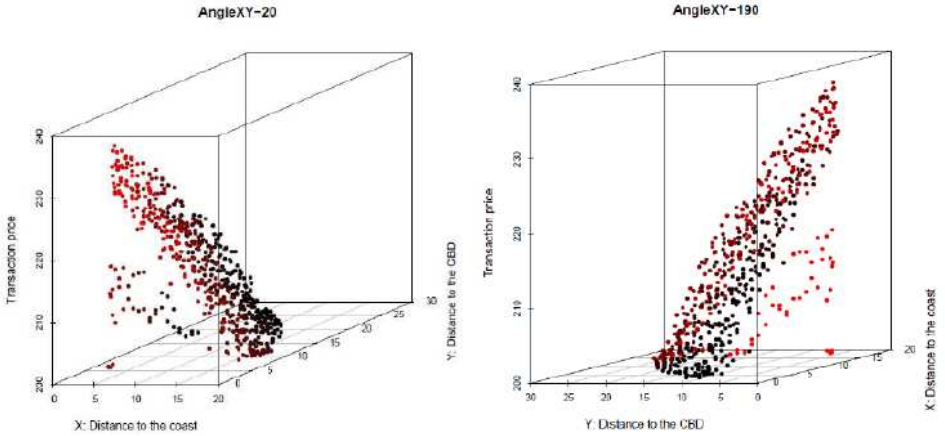
- $E(RP_{dev}) = 0$

Experiment 3: *heterogeneous risk perceptions*

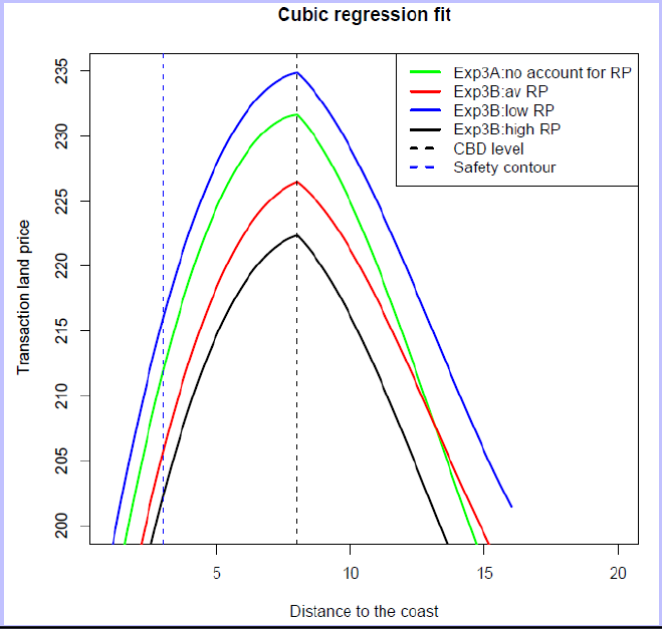


- Settings:
  - Landscape: probability of erosion has increased due to climate change
  - Agents:
    - homogeneous preferences for location
    - subjective perception of erosion probability, i.e. rational decision makers
- Things to see:
  - Different rents at equal distances
  - City has shifted landwards
  - But there are developments beyond the 'safety contour'

Experiment 3: 3D rent gradient



Experiment 3: 2D rent gradient



Experiment 2&3

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- Individuals with low risk perception drive urban developments in the zone which a representative agent considers economically inefficient
- Low coastal risk awareness is one of the reasons of human pressure and increasing coastal squeeze

Conclusions: methodology

- Spatially explicit land market model structure

  Allows tracking links between individual behaviors and emergent macro outcomes

  - Compared to urban economics:

    a land market is modeled in a *spatially explicit way,* with *heterogeneous* spatial environment, *heterogeneous* agents, and direct modeling of *interactions*;

  - Compared to cellular automata land use models:

    adds a *behavioral component* to the cellular grid;

  - Compared to statistical spatial models:

    allows *understanding the processes behind the aggregates*.

Conclusions: practice

- Human pressure and growing environmental risks
  - Response of urban developments to the increased probability of erosion caused by climate change:

    Model based on a rational representative agent predicts that economic agents adapt by moving developments landwards
  - If economic agents have subjective heterogeneous risk perception:

    Emergent prices and patterns are qualitatively different => be conscious while using representative agent model for policy decision support;

    Individuals with low risk awareness drive urban developments to economically inefficient areas => increase total potential damage and coastal squeeze

Discussion

Thank you for your attention!

Questions and comments are very welcome