Scales in coastal land use: policy and individual decision-making (an economic perspective)

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Climate change and increasing sea levels directly affect opportunities for land-use development in coastal zones. This is especially relevant for the Netherlands where the most highly developed areas and main centres of economic activity occupy land that lies below sea level. According to the concept of Integrated Coastal Zone management (Ministerie van Verkeer en Waterstaat Rijkswaterstaat 2002), coastal management and spatial planning policies should be coupled to promote safety along the coast. More severe storms and sea-level rise will shift the erosion line (this line identifies the part of the land surface that will erode during a storm surge) landwards making economic developments in coastal areas more vulnerable. Potential damage from flooding increases not only because of the shifting erosion line but also because of current economic investments (i.e. land value growth in coastal zones).

Figure 1. *Safety lines for the town Bergen aan Zee, the Netherlands*

Traditionally the Dutch Government assures a certain safety level for territory in the coastal area. However,

by applying updated methods to determine the probability of flooding (Ministry of Transport Public Works and Water Management 2005), parts of some coastal towns appeared to be legally unprotected (Ministerie van Verkeer en Waterstaat Rijkswaterstaat 2002). The total damage for 13 coastal towns not protected by dykes is €6.607 million (Ministerie van Verkeer en Waterstaat Rijkswaterstaat 2005). Figure 1 presents the case of Bergen aan Zee — a coastal town in the province Noord-Holland in the Netherlands. The area, which is on or in front of the flood defences (marked as a thick black line here — *Kernzone*) has no legal protection level with respect to coastal erosion or flooding. Moreover, the position of this line is dynamic (the dotted line indicates the predicted future position — *Beschermings* zone) and is shifting landward.

A special commission — Commission of Poelmann — was initiated to address the problem of these coastal towns at risk. According to the Commission's decision (Commissie Poelmann 2005) future developments in the areas outside the dykes are at the risk of individuals involved. This implies that it is up to individuals to decide whether to locate/to invest in these areas, which have no legal protection level with respect to coastal erosion or flooding. Thus, *the location decisions of individual agents (e.g. households, businesses) are highlighted.*

Motivated by the case study in the Netherlands, we raised the following research question: How do aggregated outcomes such as land prices and land patterns emerge from the location decisions of many individuals interacting with each other? The choice of an individual to buy a land plot/house in a certain location depends on his preferences for the spatial good and disposable income as well as available information on the environment (competition on a housing market, policy regulations and zoning, characteristics of the supplied spatial goods). In the coastal zone area the issue of flood risk may become important. Thus, the choice of a location also depends on individual risk perception, which can differ among people. A risk-averse person would prefer to invest in a safe area. However, a risk-seeking individual might want to buy a house/land plot close to the seaside. For some coastal towns this means that the investment will be done in an area that is not legally protected but may offer other benefits such as scenic value that attracts households and tourists. So, depending on individual risk perception, an economic agent makes a trade-off between safe but less scenic areas versus risky but more amenity-rich zones. When several options are weighted and the desirable good is found an individual tries to buy it. Willingness to pay (WTP) for a land plot/house and market interactions with the trading partner together determine the actual price of a spatial good (land plot or house). In turn the economic value of the property is the basis for calculating flood damage (Ministry of Transport Public Works and Water Management 2005). Potential damage from flooding is a criterion for coastal zone managers who decide what level of flood protection to provide. Thus, theoretically, the greater the number of risk-averse individuals who decide to invest in the areas outside dykes, the greater the chance that the level of safety there will increase (e.g. the erosion line by means of coastal protection measures will move seawards).

These links between individual behaviours and phenomena at the macrolevel are known as an aggregation problem or problem of scales in economics (Axelrod 1997; Veen and Otter 2003). Traditionally the aggregation problem in economics is solved with the help of a representative agent approach. The idea of a representative consumer and producer assumes that there is a behaviour model of an agent, which can be expanded to the whole set of agents in the current economy. Actually, the micromodel is supposed to be directly used at a macrolevel using aggregated macrodata. However, this approach is criticized for being unable to show the diversity of economic behaviours and interactions between agents (Arthur *et al.* 1997a; Kirman 1992). Agent-based computational economics (Judd and Tesfatsion 2006) proposes an alternative way to deal with the scaling issue in economics. The use of the agent-based modeling (ABM) technique implies heterogeneity among agents, implicit modeling of agents' interactions and cross-scale dynamics.

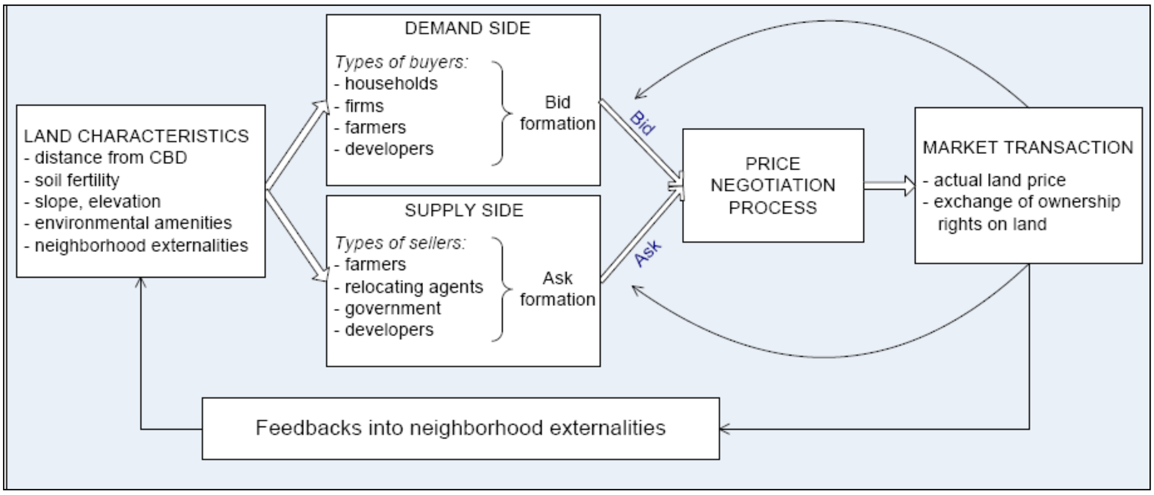
We applied an ABM technique to study the land-use change in the coastal cities in the Netherlands. As the case study highlights *individual behaviour*, it is crucial to model it explicitly. The aggregated results, such as economic value of land and potential damage from flooding are the outcomes of the *interactions* between economic agents. We started from the explicit modeling of the market for land/housing and constructed an ABM ALMA (Artificial Land MArket) (Filatova *et al.* 2007).

Markets are the economic institutions through which market goods (a land plot or house in our case) are allocated and prices are determined. ABM has been successfully used in modeling economic markets from the bottom upwards since the mid-1990s (Arthur *et al.* 1997b; Gode and Sunder 1993). There are several examples of modeling land markets with ABM discussed in Polhill *et al.* (forthcoming). The ALMA model differs from the works of others because it implies the *direct modeling of price formation and market transactions*. In comparison to other land-use models, which are usually only demand-driven (White and Engelen 2000), the land-market ABM that we present considers *both the demand and supply side of the market*. The scheme in Figure 2 represents the concept of the model.

The location choices of agents are based on their preferences expressed in the form of utility function $U = U(D, E)$. Spatial good (house/land) is characterized by the distance (D) from the central business district (CBD) and availability of environmental amenities (E, such as a seaside view). The choice of location is constrained by the available budget $Y = T(d) + R$, where *Y* is a disposable budget for a spatial good, *T(d)* are transport cost to the CBD and *R* is price for land the person can afford.

Figure 2. *Conceptual scheme of the land market*

Based on land characteristics and their own preferences, buyers and sellers of spatial goods form their



WTP and willingness to accept (WTA). The bid and ask price is a function of WTP/WTA and the situation on the market (relative number of buyers and sellers). The agents negotiate with potential traders over the transaction price. If negotiation is successful, then the market transaction takes place. The current transaction prices on land influence decisions over prices in the next time periods. Moreover, if a land parcel is transferred to a specific land use, the altered land use feeds back into the spatial neighbourhood, e.g. the density of the area and availability of open space changes when a land/house in the neighbourhood is sold, or the socio-economic characteristics of the neighbourhood change when land is occupied by a new owner.

The ALMA ABM is written in NetLogo 3.1.4. The events follow the sequence as showed in Figure 3. At this stage we model the land market only for the urban area. The behaviour of households looking for houses (demand side) and the ones who want to move (relocating agents – supply side in Figure 2) is modeled. Our main aim at the moment is to be able to include theoretical foundations of spatial economics into a spatially explicit framework. We decided to show some traditional research tasks modeled with our artificial land market model, which spatial economists usually investigate. Perception of risk of flooding is not included in the location choice at the moment; however, the model can be easily extended.

If we run the ALMA model with sellers whose asking price is equal to the agricultural land rent we get the

Figure 3. *Sequence of events*

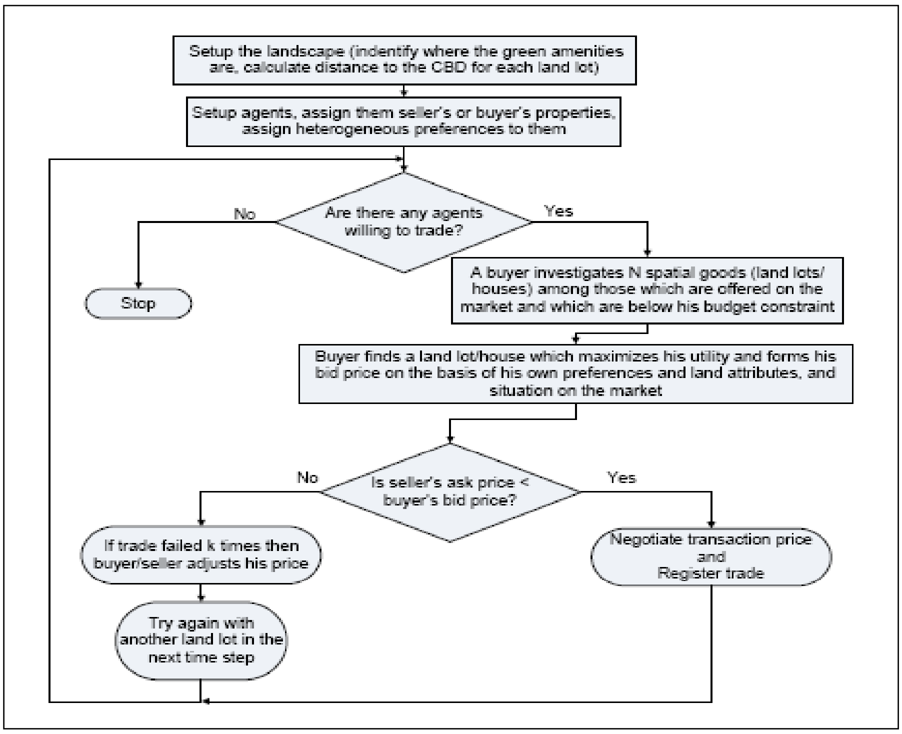
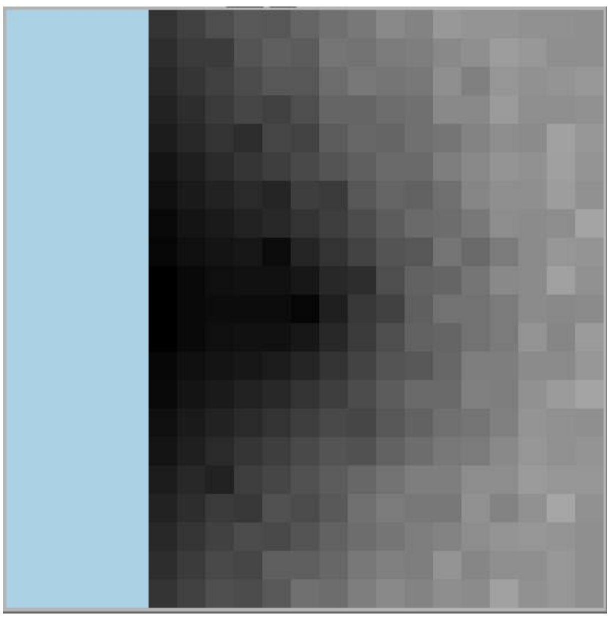


Figure 4. *Rent gradients of the coastal city*



typical rent gradient for the monocentric city as in Alonso's model (Alonso 1964). The land prices decrease with the distance to the centre. If green amenities are present in the city then the land values in their neighbourhood are higher as hedonic studies show (Wu *et al.* 2004). So, ABM with heterogeneous agents, expressing their WTP and WTA, negotiating prices and updating their WTP/WTA is able to reproduce the macrophenomena (land prices and land patterns) predicted by spatial economic theories. Figure 4 shows the land gradients in the coastal city as a result of location and bidding choices heterogeneous individuals.

The city center is in the middle and sea is presented by the plain blue area at the left. The main difference with the standard representative agents framework is that we are able to derive land rent gradients with *heterogeneous* agents and diverse land attributes. Our next step is to include risk perception in the behavioural function of economic agents and study how agents sort themselves among municipalities providing a lower/greater safety level, the difference among land prices in safe and vulnerable areas and how land prices change with changes in people's risk perception.

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